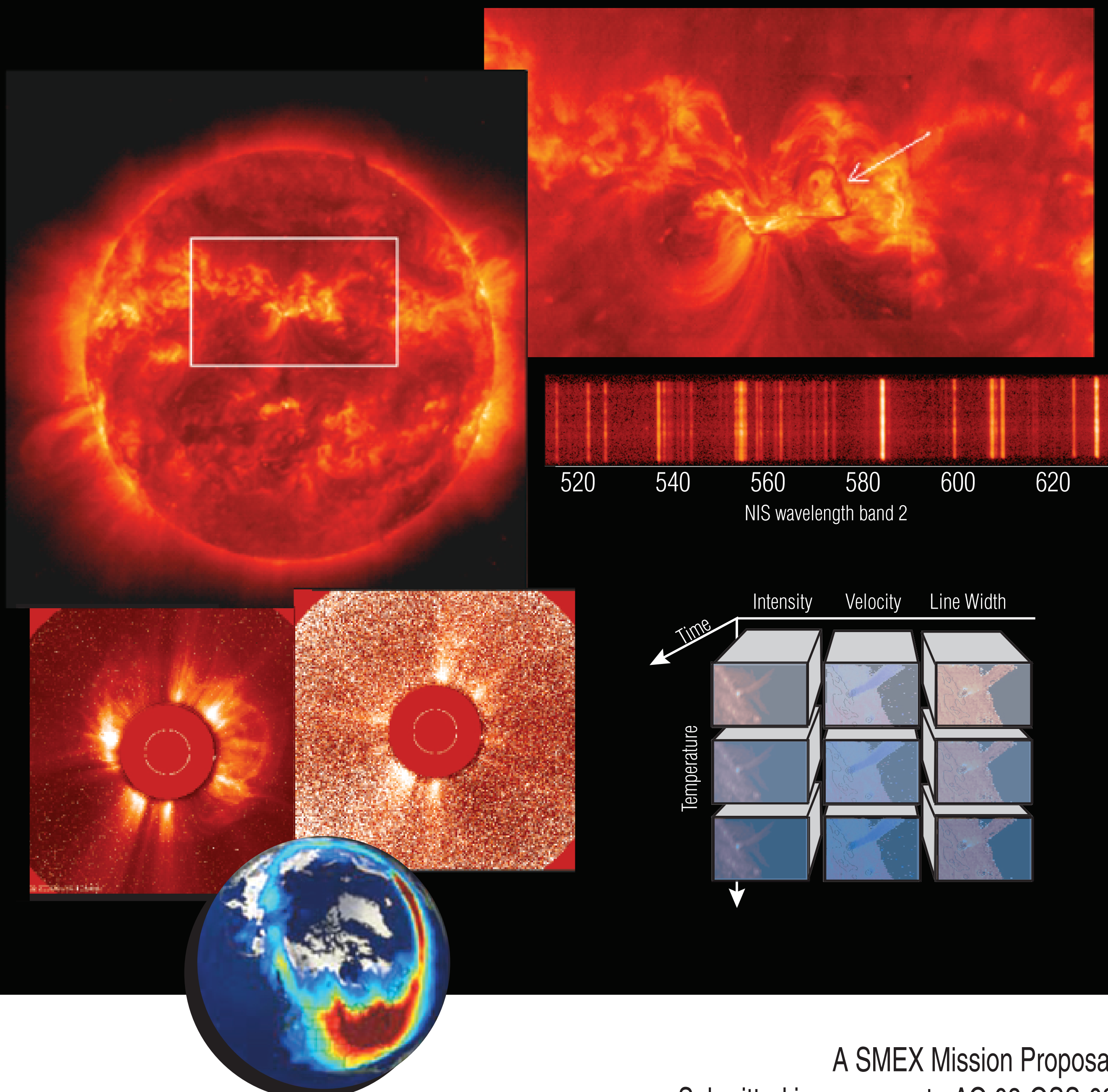
Normal-incidence EXtreme Ultraviolet Spectrograph

(NEXUS)

An Investigation of Coronal Dynamics



A SMEX Mission Proposal
Submitted in response to AO 03-OSS-02
Principal Investigator: Joseph Davila, NASA/GSFC
May 2, 2003

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

April 28, 2003

Reply to Attn of: 600

TO: NASA Headquarters
Attn: S/Associate Administrator for Space Science

FROM: 100/Director

SUBJECT: Normal-incidence Extreme Ultraviolet Spectrograph (NEXUS) Proposal

Enclosed is the Normal-incidence Extreme Ultraviolet Spectrograph (NEXUS) proposal in response to NASA's Announcement of Opportunity AO 03-OSS-02. We are very excited about the NEXUS mission, which will revolutionize our understanding of the solar corona. The NEXUS instrumentation will conduct observations that will provide physical insights necessary for the prediction of space weather in the Sun-Earth system, putting this mission at the heart of the Sun-Earth Connection Theme.

The NEXUS mission represents the next generation of spectrograph for solar coronal research. NEXUS is the result of a breakthrough optical design that incorporates new technologies to achieve high optical throughput at high spatial and spectral resolution over a wide field of view in an optimal extreme-ultraviolet spectral band. NEXUS blends solid flight heritage with state-of-the-art innovation to provide a reliable, low-cost, mission for the Explorer Program.

Goddard Space Flight Center has been a world leader in solar spectroscopy for the past 30 years. Much of the technology that has made NEXUS possible has been developed at Goddard and demonstrated on previous orbital missions, and on the Solar Extreme-ultraviolet Research Telescope and Spectrograph (SERTS) sounding rocket instrument.

In conclusion, I assure that the scientific, engineering, management, facility, and other support that is necessary for the on-time and within budget delivery of the NEXUS investigation will be available and committed to the mission. With this understanding, I fully endorse this proposal.

A. V. Diaz

Enclosure

PROPOSAL COVER PAGE

(Date : Apr 23, 2003)

SMEX03-0043-0020

Name of Submitting Institution: Goddard Space Flight Center **Congressional District:** N/A

Certification of Compliance with Applicable Executive Orders and U.S. Code

By submitting the proposal identified in this Cover Sheet/Proposal Summary in response to this Research Announcement, the Authorizing Official of the proposing institution (or the individual proposer if there is no proposing institution) as identified below:
- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in the two Certifications contained in this NRA [namely, (i) Assurance of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs, and (ii) Certifications, Disclosures, And Assurances Regarding Lobbying and Debarment & Suspension]. Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

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[3] ... Proposal Title (Short and/or Full)

Short Title:	NEXUS
Full Title:	Normal Incidence Extreme Ultraviolet Spectrograph (NEXUS)

[4] ... Themes

(1) Sun-Earth Connection

[5] ... Predecessor Information

Predecessor Information:	None

[6] ... Summary

The Goddard Space Flight Center (GSFC), in collaboration with the Naval Research Laboratory (NRL), the University of California (UCB), and Rutherford Appleton Laboratory (RAL),proposes a next generation Normal-incidence Extreme-Ultraviolet Spectrograph (NEXUS).

NEXUS is designed to observe the fundamental physics responsible for regulating the flow of energy through the chromosphere and corona. The chromosphere/corona is the source region for solar wind. Therefore understanding the energy flow in these regions is essential for predicting solar influences throughout the heliosphere. NEXUS will support the Sun Earth Connection (SEC) program by providing observations relevant for the science objectives identified in the 2003 SEC Roadmap.

[7] ... Cage Code, Duns, TIN

Cage Code:	25306
DUNS Number:	
TIN Number:	52-0734375

[8] ... Institution Type

Institution Type:	NASA Center

[9] ... International Proposal

International Participation & Description:	Yes (Instrument calibration and ground station)

[10] ... **Program**

Program Selection:	ELV:SELV KSC contract

[11] ... **Sproptype**

Proposal Type:	SMEX

[12] ... **Data1**

For Missions of Opportunity:	

[13] ... **Data2**

For ISS attached payload only:	

[14] ... **AddInfo**

New Technology:	

[15] ... **AOBudget**

NASA OSS Cost (FY2003 $):	$119,999,800.00
NASA OSS Cost (RY $):	$131,109,800.00
Total Cost (FY2003 $):	$123,169,200.00
Total Cost (RY $):	$134,718,070.00

Continue

Edit Proposal Information

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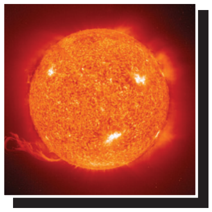
NORMAL-INCIDENCE EXTREME ULTRAVIOLET SPECTROGRAPH (NEXUS)

Joseph M. Davila (PI)

HIGHLIGHTS



On all scales, the exchange of energy in the solar transition region and corona is determined by the complex interactions between the magnetic field, the plasma, and plasma flows. How is energy transported in this highly-structured magnetic environment? This is the central unanswered problem in coronal physics. NEXUS will provide answers by measuring flows on the relevant scales, for the first time.

SCIENCE

Science Objectives

- **How are coronal loops heated?** — *Spectral observations faster than the loop sound crossing time*

- **How and where is the solar wind accelerated?** — *Definitive test of ion-cyclotron heating*

- **What initiates coronal mass ejections and other coronal transients?** — *Observe CME build-up, initiation, and relaxation with unprecedented resolution and temperature coverage*

- **What are the sources of ultraviolet irradiance variations?** — *Discover physics of EUV irradiance variations*

NEXUS supports the NASA Sun Earth Connections (SEC) program, *and*

- **NASA Strategic Plan** - *to "Understand and protect our home planet: by providing the essential scientific foundation for prediction of natural hazards in the near Earth environment,*

- **2003 Sun-Earth Connection Roadmap** - *"Understanding the changing flow of energy and matter throughout the Sun," by studying energy flow in the corona,*

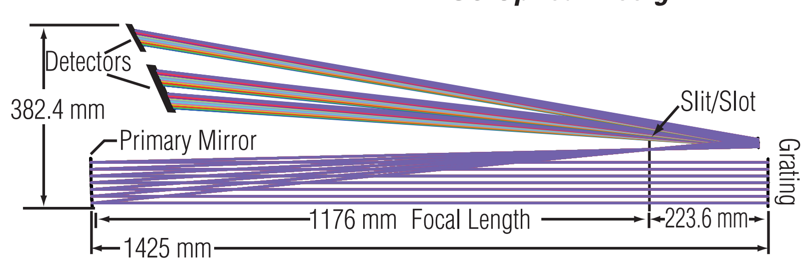
- **2002 National Academy of Science Solar and Space Physics Survey Committee** - *addressing all four of the Science Challenges identified in the report,*

- **NASA Living With a Star (LWS)** - *providing the essential scientific knowledge needed to understand the origin of EUV irradiance variations, thereby providing a scientific foundation for the development of tools to predict space weather.*

MISSION

- *No technology development*
- *Robust contingency and margin*
- *2 year mission, Pegasus launch*
- *600 km Sun-synchronous polar orbit*
- *15 Gbit/d downlink; 4 passes/day of 10 minutes each*
- *MOC/SOC at GSFC (TRACE & SOHO heritage)*
- *Ground station at RAL (ACE heritage) with commercial backup*
- *Open data policy*

NEXUS Optical Design



SCIENCE PAYLOAD

Breakthrough capabilities, with

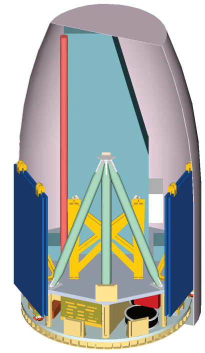
- *Simultaneous spectral line profiles in the 0.02 to 15 MK temperature range in 3 spectral bands*
- *Large A_{eff} (26xSOHO/CDS)*
- *<2km/s accuracy in Doppler velocity*
- *10% accuracy in intensity and line widths*

Instrument Characteristics

Spatial resolution	1 arcsec per 2 pixels
Field of view (slit)	(0.5, 1, 2) x 1000 arcsec
Field of view (slot)	60 x 1000 arcsec
Wavelength bands	457-425; 566-631; 743-800 Å
Exp Time (active regions)	1.6 s
Exp Time (quiet Sun)	8 s
Velocity resolution	2 km/s
Temperature Coverage	0.02-15 Mk

S/C CHARACTERISTICS

- *S/C Bus based on the Spectrum Astro SA-200B Bus*
- *Minimal modifications to the RSDO core bus*
- *Flight Heritage from Mighty Sat II.1 and RHESSI*
- *Substantial reuse of avionics*
- *Structural modification to accommodate instrument*
- *Robust design with large margins throughout*
- *Excellent compatibility with LV: mass, volume, PAF, and substantial shroud clearances*
- *Full compatibility with STDN-Class ground station/MOC at X-Band, including CCSDS protocols*

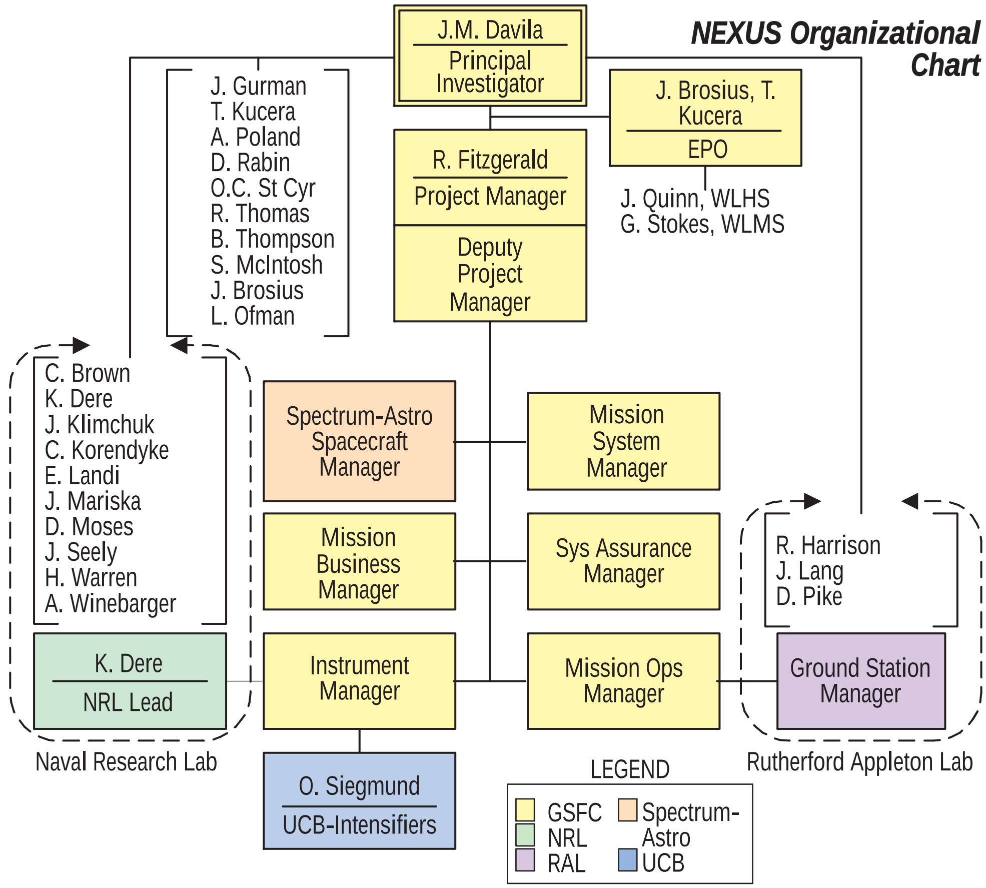


NEXUS easily fits in Pegasus fairing

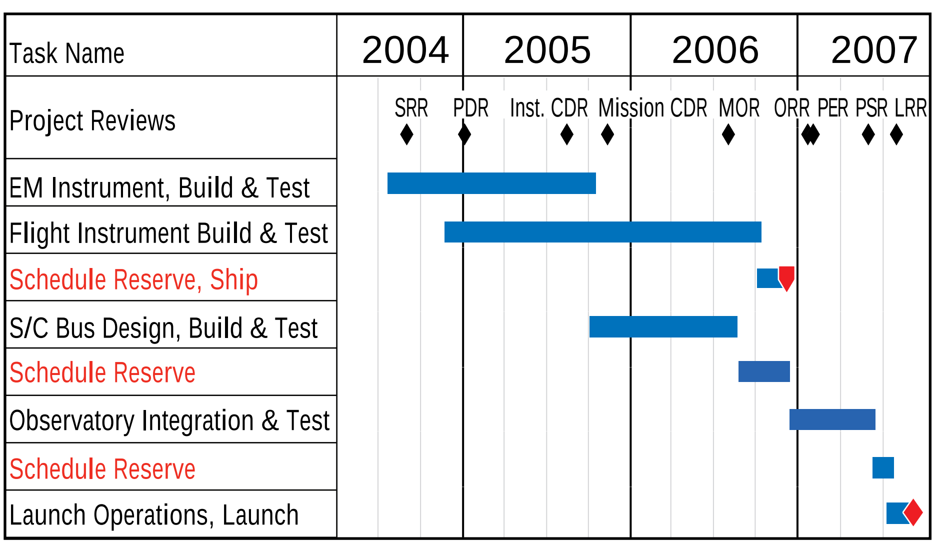
MISSION MANAGEMENT & RESPONSIBILITIES

- *Overall mission managed by Goddard Space Flight Center*
- *Instrument developed by GSFC and NRL*
- *Collaboration with UCB for intensifiers*
- *Collaboration with RAL for calibration, and ground station*
- *Spectrum Astro provides spacecraft*
- *Experience development team*
- *Graceful degradation of science from the Baseline to the Minimum Mission*

NEXUS Organizational Chart



SCHEDULE & COST



Cost Summary

NASA-OSS Cost in FY03$

Mission Development	$ 67,106K
Contingency	$ 18,707K
Launch Vehicle	$ 27,311K
MO&DA/EPO	$ 6,876K
TOTAL	**$120,000K**

Summary

- *Low risk*
- *Exceptional science*
- *Heritage hardware*
- *Robust resource margins*
- *Experienced team*

Mama always told me not to look into the eyes of the Sun; But Mama, that's where the fun is.
-- Bruce Springsteen, "Blinded by the Light"

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D SCIENCE INVESTIGATION

Executive Summary

Overview: The intermittent flow of energy from the transition region to the solar corona, determined by the complex interplay between the magnetic field and plasma motions, is poorly understood. A wide variety of solar activity phenomena, ranging from slowly evolving small-scale features such as active region loops, to rapid large-scale eruptive events like Coronal Mass Ejections (CME), result from this energy flow. These events shape and modify the entire heliosphere, driving the near-Earth environment and producing space weather effects that can have significant societal impacts.

The Normal-incidence Extreme Ultraviolet Spectrograph (NEXUS) will provide new and unique measurements that will quantify the role of plasma flows in a range of dynamic phenomena, revealing the fundamental physics of energy and mass transport in the solar corona. These measurements can only be obtained with an imaging spectrograph (Figure 1) with capabilities that exceed those of any similar instrument that has previously flown. As we will demonstrate, NEXUS is the result of a breakthrough in spectrograph design to perform the necessary measurements on the critical spatial and temporal scales. This will be accomplished within the resources of a SMEX mission with robust margins.

We propose a combined spectroscopic and imaging investigation of the dynamics of the solar corona aimed at understanding:

a. How are coronal loops heated?
b. How and where is the solar wind accelerated?
c. What initiates coronal mass ejections and other coronal transients?
d. What are the sources of solar ultraviolet irradiance variations?

These questions, which are the focus of NEXUS, are of fundamental importance to NASA and to the Sun Earth Connection theme. NEXUS will support the NASA Strategic Plan "...Protect the Planet" initiative by providing the essential scientific foundation for the development of tools to predict the near-Earth space weather environment, and the 2003 Sun-Earth Connection Roadmap by providing observations necessary for "Understand[ing] the changing flow of energy and matter throughout the Sun ...". NEXUS also addresses all four of the Science

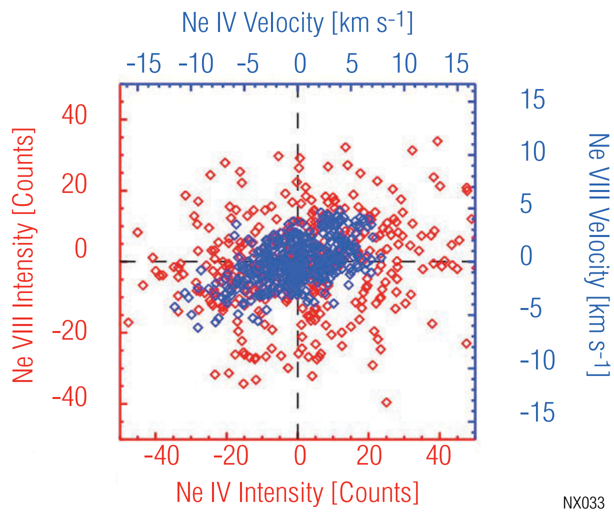


Figure 1: Observed velocities (blue points) correlate, while intensities (red points) do not, indicating a physical connection only visible in a spectrograph like NEXUS. (From SUMER)

Challenges identified in the report of the 2002 National Academy of Science Solar and Space Physics Survey Committee. NEXUS supports the NASA Living With a Star (LWS) program by providing the essential scientific knowledge necessary for understanding the fundamental physical processes at work in the corona.

Instrument and Spacecraft: NEXUS uses existing technologies in an innovative spectrograph design to achieve high optical throughput at high spatial (0.5 arcsec) and spectral (1-2 km/s) resolution over a wide field of view (FOV) in an optimal extreme-ultraviolet spectral band. NEXUS will be able to observe anywhere on the disk, and in the corona out to 2.5 Rsun. The instrument consists of a single off-axis parabolic mirror telescope, a single grating spectrograph, interchangeable spectrograph slits and slot, and intensified Charge Coupled Device (CCD) detectors. Superior performance is further enhanced with a highly reflective broad band coating to maximize throughput, cadence, and temperature coverage.

The NEXUS spacecraft (S/C) is based on the Spectrum Astro SA-200B bus as defined in the NASA GSFC Rapid Spacecraft Development Office (RSDO) Rapid II catalog. Most recently this bus was used for the highly successful RHESSI SMEX mission. NEXUS will be launched into a Sun-synchronous orbit in 2007 aboard a SELVS II Pegasus XL. NEXUS components are based on well-understood, flight-proven technologies to minimize risk and cost. NEXUS resources are well within those specified in the SMEX AO.

Proposed Observations: NEXUS will record spectral line profiles in three bandpasses chosen to include lines that densely span the 0.02 - 15 MK temperature range. The high throughput will provide at least a 10% statistical accuracy in line intensity, a 1–2 km/s accuracy in net Doppler velocity, and 10% accuracy in line width for exposure times of 0.5 s in active regions. Large portions of the solar disk will be rastered at a high cadence. Full Sun rasters at a reduced resolution of 2 arcsec can be completed in 24 min to obtain simultaneous spectrally pure images over the full temperature range covered by NEXUS. Simplified observing programs that incorporate synoptic full Sun rasters will be combined with long duration, high-cadence programs that follow large-scale solar features such as active regions, filaments, and coronal holes. This observing strategy will simplify commanding and keep operations costs to a minimum.

NEXUS was designed to accomplish its science objectives operating independent of other missions. Rastered images will provide the needed context and coalignment information with 0.5 arcsec spatial resolution. However, with a planned launch in 2007, NEXUS will both complement and supplement other solar missions such as Solar-B, STEREO, and Solar Dynamics Observatory (SDO). NEXUS data will provide the needed chromospheric and transition region observations to link the photospheric and coronal observations on Solar-B. The ability of NEXUS to observe the build-up and initiation of a CME while SECCHI provides unprecedented measurements of the low corona and the interplanetary medium propagation will provide a powerful diagnostic tool to investigate the CME phenomenon. The high-resolution images and magnetograms obtained by SDO will be valuable additions for the analysis of NEXUS spectral data. NEXUS extends the capability of the SDO mission by providing needed Doppler velocity information and high-resolution narrow band images in transition region lines not available from SDO instrumentation.

NEXUS Team: The NEXUS investigation will be carried out by a team that has successfully designed, constructed, and operated numerous complex flight instruments. The NEXUS Science Team also has demonstrated expertise in solar data analysis, theoretical and numerical modeling of the Sun-Earth system, and education and public outreach.

D.1 Science Goals and Objectives

NEXUS investigates the central unsolved problem of coronal physics—how energy is transported in a structured magnetic environment—by observing rapidly enough to determine the role of material flows in the energy balance. This can only be accomplished with a spectrograph like NEXUS. For each of the following science objectives, observations and their required durations are identified and later (D.2) these are used to develop the instrument requirements

D.1.a How are coronal loops heated?

Three decades after observations from Skylab conclusively demonstrated that coronal plasma is contained within magnetic loops, the question of how those loops are heated remains unanswered. It is not even clear whether the heating for a given loop is uniform and steady[1] or impulsive and local[2]. For example, the heating in a particularly well studied SXT loop has been variously found to be uniform[3], concentrated near the footpoints[4], and concentrated near the apex[5].

Images alone are insufficient for unraveling the physics of loop heating. For example, the top panel in Figure 2 shows one image from a set of TRACE active region observations. The images showed no significant changes over several hours, making it impossible to discriminate between steady state and static models. Yet the Dopplergram constructed using SUMER spectra displayed in the bottom panel shows that flows with speeds up to 40 km/s were present[6]. Recent observations have provided evidence that flows at loop footpoints observed in lines formed at different temperatures are time varying and correlated[7] (Figure 1). Only Doppler shift measurements provide a window into the velocity-related terms in the energy balance of coronal loops—an essential requirement for understanding how coronal loops are heated.

Without a basic knowledge of the duration, magnitude, or spatial distribution of the heating, it has not been possible to discriminate among the competing loop heating theories. On roughly a sound crossing time (loop length/sound speed), the plasma structure in a loop loses all "memory" of the details of the heating mechanism. Thus, it is necessary to observe the full length of a loop in less than the

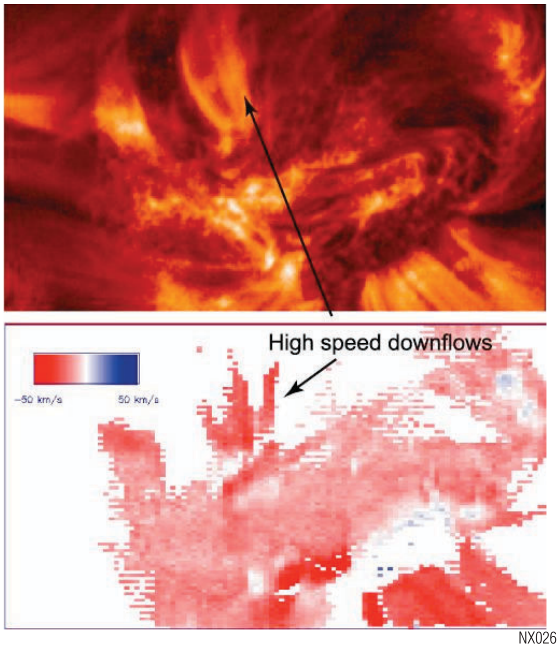


Figure 2: TRACE image shows an apparently static loop (top); SUMER velocity map reveals high-speed flows (bottom).

sound crossing time (Figure 3). NEXUS will be the first such instrument to provide these critical measurements.

The heating mechanism of coronal loops is presently unknown (Foldout 1A). Resonant dissipation of Alfven waves was suggested by Ionson[8] as a possible heating mechanism, and has been extensively studied (e.g., [9]-[15]). Recently, Ofman, Klimchuk, and Davila[16] have shown that evaporation of chromospheric material into the coronal loops plays an important role in loop heating. Heyvaerts and Priest[17] suggested heating by phase mixing of Alfven waves. Using TRACE observations of damped loop oscillations Ofman and Aschwanden[18] have shown that phase mixing may occur in these loops.

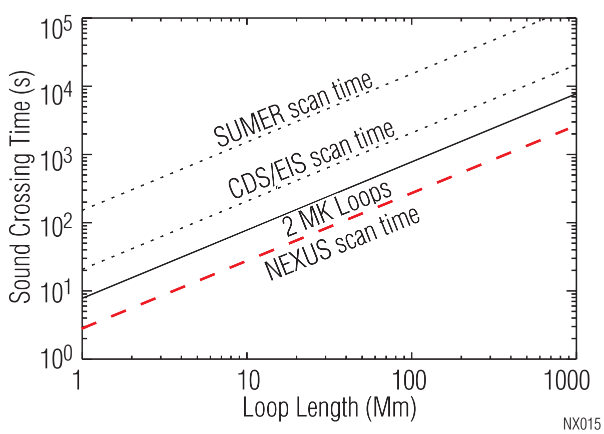


Figure 3: Simulations showing that very different heating profiles converge to a common temperature-density structure after a few sound crossing times.

NEXUS will observe two primary signatures of resonant Alfven wave heating: emission line broadening of minor ions in the loops at coronal temperatures due to unresolved Alfvenic fluctuations, and time-resolved motion of coronal loops due to loop oscillations similar to the ones detected recently by SUMER in hot coronal loops[19],[20]).

Parker[21] suggested that nanoflares were responsible for heating the solar coronal plasma. However, so far the evidence for sufficient nanoflare rate from observations are inconclusive (e.g., [22]). With its high sensitivity, NEXUS will be able to observe flares with lower energies than has been previously possible. In addition NEXUS will be able to detect expected indirect evidence for nanoflares, such as Doppler shifts due to emission from jets of hot material emanating at Alfvenic speeds from the nanoflaring sites, as well as localized Doppler broadening at the nanoflaring sites themselves.

To accomplish this science objective, we require 195 days of observation to characterize the heating rate in quiet and active region loops. Observations must be continuous within time intervals of at least 2 hr length. Observations will consist of high resolution (0.5-1 arcsec) rasters over a 16 x 1-4 arcmin FOV with raster cadence of 0.7-10 min in active regions and sit-and-stare observations with 0.5 arcsec spatial resolution at 2.6 s cadence to characterize temporal variability. This objective will be fully accomplished using a subset of the observations obtained to characterize CME initiation, discussed in D.1.c.

D.1.b How and where is the solar wind accelerated?

The open magnetic field regions where the solar wind originates constitute a physical environment distinct from those of closed field regions. Thus, knowledge of the sources of the solar wind, its velocity and acceleration, are essential components for understanding the flow of mass and energy through the solar corona.

The source regions of both the slow and fast solar wind have not been clearly determined. Sheeley et al., [23] locate the origin of the slow solar wind near the base of the streamers at around 2 solar radii, but little is known about its signatures at lower altitudes. Dere et al.,[24] and Hassler et al.,[25] found that the fastest flows in coronal holes come from regions associated with the chromospheric network; but Dupree et al.,[26] and Landi et al.,[27] showed that the dominant part of the solar wind material originates from intra-network regions. However, all of these studies were compromised by instrumental limitations. With its large FOV, high sensitivity, spatial and velocity resolution, and broad temperature coverage, NEXUS will overcome these limitations.

Source regions of the solar wind on the disk will be identified through a combination of intensity and Doppler shift maps in lines spanning the chromosphere to corona. These data will be obtained from observations taken to satisfy objective D.1.c.

SOHO/UVCS observations have shown that in the interplume regions of coronal holes, the width of the OVI line increases dramatically in the range $1.5 \le r \le 2.5$ Rsun, i.e., in the acceleration region of the solar wind (Foldout 1B).Linewidths measured by SUMER are inconclusive, but hint at an increase in linewidth at 1.4 Rsun.[28],[29]. These observations have been interpreted as the signature of the dissipation of a spectrum of high-frequency collisionless ion-cyclotron waves via gyro resonance with ion cyclotron Larmor motions [30],[31],[32]. But, the UVCS observation is limited to O VI only, at a single value of charge-to-mass (q/m) ratio. If a spectrum of ion-cycloton waves exist, other ions with different, but similar values of q/m must also be heated. NEXUS will measure the line width for ions with different q/m ratios that are resonant with different portions of the ion-cyclotron wave spectrum. Measurements of linewidths in the range $1.5 \le r \le 2.5$ Rsun will thus provide a definitive test of the ion-cyclotron wave theory.

To fully characterize the line widths of O IV, O V, and He I in coronal holes, we require 30 days. Low spatial resolution (1.6 arcmin) observations in the range $1.5 \le r \le 2.5$ Rsun will be obtained. To obtain sufficient signal-to-noise, 10-100 images with 100 s exposure times will be co-added on the ground. A wide 2 arcsec slit will further maximize throughput of the instrument.

D.1.c What initiates coronal mass ejections and other coronal transients?

Coronal mass ejections are one of the most spectacular manifestations of the episodic transfer of mass and energy from the Sun to the heliosphere. The corona is able to expel large plasmoids at velocities beyond 2000 km/s. Acceleration time scales range from minutes to hours. Spatial scales approach nearly a solar radius or more, and their energies are usually larger than that of the flares that often accompany the CME. The shock waves created at the leading edge of the CME accelerate particles to high energies. These energetic particles and the CME itself often impinge on the Earth's magnetosphere and create large disturbances in the Earth's space weather.

How the corona is able to generate CMEs largely remains a mystery. We know they originate along magnetic neutral lines often associated with active regions and filament channels. Magnetic field models of filament channels suggest that these are the sites of some of the most highly non-potential fields found in the corona—making them likely sites of eruption. However, the energy found in CMEs is considerably higher than that available along a filament channel. Further, how these fields evolve toward an unstable configuration is not understood, although it is thought to be associated with magnetic reconnection.

There are three broad classes of CME initiation models, characterized by the location of reconnection. In the flux rope models (e.g., [33]), reconnection at the photosphere leads to the formation of a growing flux rope which eventually loses equilibrium and erupts. In the tether-cutting models (e.g.,[34]), reconnection inside the strongly sheared field of the filament channel destabilizes the system. Finally, in the break-out model, reconnection in the corona above a filament channel leads to eruption (e.g.,[35]). NEXUS will discriminate among these models by observing evolution of the filament structure prior to eruption, looking for high speed jets that mark the reconnection site and observing the energy distribution in the post-eruptive plasma.

The requirements for such observations are considerable. CMEs and filaments are large scale structures (~ a solar radius) whose velocities early in an eruption are only a few km/s. Reconnection events are observed on small spatial scales (~1 arcsec) with high velocities. A wide temperature range is required to observe both the cool filament plasmas and the hot coronal loops. NEXUS is the first instrument capable of accomplishing such a challenging observing program (Foldout 1C).

To characterize the CME initiation process in quiet and active region loops, we require 465 days of observation taken over continuous periods no shorter than 6 hours. Neutral line targets will be identified from publicly available magnetograms. NEXUS observations will consist of high resolution (0.5-1 arcsec) rasters over a 16 x 1-4 arcmin selectable FOV with raster cadence of 0.7-10 min in active regions and sit-and-stare observations with 0.5 arcsec spatial resolution at 2.6 s cadence to characterize temporal variability. High cadence (2.6-54 s) slot rasters will provide simultaneous monochromatic images with 0.5-2 arcsec spatial resolution in active regions, and 11-40 s slot rasters in quiet Sun areas. Assuming the (conservative) solar minimum CME rate of 0.5 event/day, NEXUS will observe approximately 40 CMEs on the Earth-facing hemisphere of the Sun during the mission.

D.1.d What are the sources of solar ultraviolet irradiance variations?

Solar radiation at extreme ultraviolet (EUV) and soft X-ray wavelengths (1-1200 Å) is a major energy loss from the transition region and corona. Moreover, this radiation largely determines the baseline properties of the Earth's environment at altitudes above about 100 km (Foldout 1D). Variations in solar EUV radiation drive substantial changes in thermospheric temperature, density, and ionization (e.g., [36]) that produce space weather impacts over multiple time scales. For example, solar EUV-induced fluctuations in electron density affect the performance of ground- and space-based communication systems, and neutral density changes alter the trajectories of low Earth-orbiting and reentering spacecraft (S/C). Despite its importance, our knowledge and understanding of the coronal spectrum is fragmented, incomplete, and imprecise.

The disk-integrated spectrum, or spectral irradiance, has been measured with a variety of instruments flown on sounding rockets and satellites, but the individual observations are deficient (e.g., [37]). In lieu of adequate monitoring, semi-empirical models of the variable spectrum have been developed based on proxies such as the Lyman-α and 10.7 cm radio fluxes (e.g., [38],[39]). While this approach is useful in the short term, accurate real-time specification and forecasting of the complete X-ray and EUV spectrum can only be achieved through physics-based modeling. This portion of the NEXUS science investigation is aimed at understanding the basic physics of the solar transition region and corona that drives the solar EUV irradiance variations. NEXUS observations can therefore be used to improve the new generation of physics-based EUV models, such as NRLEUV [40][41], resulting in more accurate solar irradiance variability predictions--a significant practical product from a basic science mission.

To achieve this objective, the slot will be rastered to obtain a 32 x 32 arcmin full Sun FOV, resulting in a set of monochromatic images at up to 6 temperatures simultaneously at 2 arcsec resolution. Each scan will require 12 min to complete depending on the number of lines obtained. Periodically, 2 arcsec spectral rasters of the full solar disk will be taken over a duration of 45 min to provide correlative velocity information. Full disk scans will be accomplished 4 times/day resulting in a commitment of 72 observing days of the mission to develop the correlation between temporal and spatial EUV irradiance variations. High resolution (0.5-1 arcsec) rasters over a 16 x 1-4 arcmin FOV with raster cadence of 0.7-10 [14-40] min in active [quiet] regions and sit-and-stare observations with 0.5 arcsec spatial resolution at 2.6 [27] s cadence in active [quiet] regions to characterize temporal variability will be selected from the long term scans acquired to satisfy D.1.c.

D.2 Science Requirements

The instrument, S/C, and mission requirements necessary to satisfy the NEXUS science objectives (Table 1) were derived from the total range of science requirements discussed in D.1.a-d.

We require a total of 30 (D.1.b) + 465 (D.1.b, c) + 72 (D.1.d) = 567 days of observation and a large number of uninterrupted 6 hr periods of solar observation to capture CME dynamics. To satisfy these requirements, we require a Sun-synchronous polar orbit at the dawn-dusk line at an orbital altitude of 600 km. This orbit provides long periods of uninterrupted solar viewing, and the orbital lifetime necessary for NEXUS. A SELVS Pegasus XL launch vehicle will insert NEXUS into this orbit. The Pegasus was chosen because it is the lowest cost option. NEXUS requires a 600 km altitude orbit with a 97.79±0.08 degree inclination and ±15 km Apse error. The nominal Pegasus XL launch dispersion will not meet the NEXUS orbital accuracy requirements, so a Hydrazine Auxiliary Propulsion System (HAPS) is baselined. However, the orbit and launch requirements for

Table 1: NEXUS science objectives are satisfied by flowing requirements to the instrument, the S/C, or the mission design.

Science Objective				Science Measurement Requirement	Accommodations	
a	b	c	d		I=Instrument, S=Spacecraft, M=Mission	
	X	X	X	Total observing time of ≥567 observing days	I	- 2 yr instrument design life, nearly 100% duty cycle
					S	- 2 yr S/C design life
					M	- 2 yr mission design life to satisfy total observing time
X	X	X	X	Total mission data collected 7992 Gbits	M	- Daily downlink volume of 15 Gbit/day, 172 kbps average data rate, 6.2 Mbps avg downlink rate with 40 min contact/day
X	X	X	X	Observe specific targets anywhere within r=2.5 Rsun of Sun center	I	- Off-pointing image motion of ±40 arcmin
						- Off-pointing of primary mirror ±20 arcmin
					S	- 3-axis stabilized
						- S/C stares at Sun center
						- S/C capable of rolling to an arbitrary roll angle
X		X		High cadence raster measurements of specified FOV for 6 hrs or longer	I	- Instrument to provide onboard storage ≥10 Gbit - Temporal resolution < 10 s - FOV ≥ 1 solar radius
					M	- Polar, Sun-synchronous orbit, 97.79 deg inclination for continuous solar viewing - Peak downlink rate 8 Mbps X-band - Daily downlink volume of 15 Gbit/day, single ground station, 6.2 Mbps avg downlink rate
X		X		Obtain simultaneous observations to spatially resolve 350 km CME and loop structures with a temporal resolution ≤3 s in active regions	I	- Instrument spatial resolution of 0.5 arcsec/pix - Instrument effective area ≥ 150 mm^2 - Rastered FOV of order 1 Rsun - Image motion compensation (IMC) mechanism for primary mirror to remove residual S/C jitter for 0.5 arcsec imaging
					S	- ±20 arcsec RMS pointing stability - ± 5 arcsec RMS jitter - ± 50 arcsec RMS roll
X		X	X	Correlate solar features in upper chromosphere, transition region, and corona	I	- Observe emission lines formed at temperature range of 0.02-15 MK
X		X	X	Correlate observed event times with observations from other missions and ground based observatories	I	- ±0.5 s RMS jitter from absolute time
					S	- ±0.5 s RMS jitter from absolute time
X		X		Centroided Doppler velocity resolution ≤2 km/s	I	- Spectral resolution ≥36 mA/pix - ≥1000 detected photons in emission line profile/exposure

NEXUS are similar to TRACE, an earlier SMEX mission, which did not use the HAPS. During Phase A a more detailed study will be done to evaluate the necessity of the HAPS to achieve NEXUS objectives.

NEXUS requires a single ground station with 40 min total contact/day for downlinking the housekeeping and the science data and for command uploads. Goddard Space Flight Center (GSFC) will operate the Mission Operations Center (MOC) and Science Operations Center (SOC). A 24 hr observing plan will be uplinked daily from the ground station at Rutherford Appleton Laboratory (RAL).

NEXUS data products have been optimized to answer the scientific questions posed in Section D.1 above. NEXUS will simultaneously record spectral line profiles of solar coronal emission lines in 3 bandpasses chosen to include lines that span the broad 0.02 - 15 MK temperature range, to answer the four primary science questions posed in D.1. With a 16 arcmin long slit, NEXUS will raster large portions of the solar disk at a high cadence, producing data containing full spectral diagnostic information over a very large rastered FOV. In addition, using a 16 x 1 arcmin slot allows the complete solar disk to be rastered to obtain simultaneous spectrally pure images over the full temperature range covered by NEXUS (Table 2).

The photon detection rates for the strongest emission lines observed are shown in Table 2. The integration times are derived for a 0.5 arcsec slit, and the coronal flux was calculated using emissivities from the CHIANTI database[42],[43],[44] for quiet-Sun (QS) and active region (AR). Measured properties (Foldout 3E) were used for the B_4C/Ir coated optics and the KBr coated microchannel plate (MCP), Foldout 3C[45]. J. Seely calculated the grating efficiency. Slot images have the same count rate/pixel.

D.3 Science Data and Other Scientific Products

NEXUS will generate a wealth of rastered imaged spectroscopic data, with unprecedented <3 s time and <0.5 arcsec spatial resolution. A time sequence of intensity, Doppler velocity, and line width maps covering the temperature range 0.02 - 15 MK will be derived from the calibrated imaged spectra. Intensity maps will be used to track the proper motions and thermal evolution of dynamic solar features. Observed proper motions will be combined with the Doppler velocity map to develop a picture of the 3D evolution of the structures studied. Unresolved motions, either temporal or spatial, will be evident in the line width maps.

Table 2: Large effective area (~20 x CDS) of NEXUS results in minimal integration times for lines that cover a broad temperature range.

Spect Range [A]	Ion	λ (A)	Log T	Detected Photons	
				AR [ct/s]	QS [ct/s]
457-524	Ne VII	465.220	5.71	143.7	13.3
	Si XII	499.407	6.28	796.6	17.3
	Si XII	520.666	6.28	409.8	8.9
566-631	Fe XX	567.864	6.97	0.2	0.0
	Al XI	568.122	6.16	54.5	1.6
	He I	584.334	4.51	614.0	71.4
	Fe XXI	585.790	7.02	0.0	0.0
	Fe XIX	592.236	6.90	0.9	0.0
	O III	599.601	5.03	79.6	13.1
	2x He II	607.560	4.92	23.4	3.6
	Mg X	609.794	6.05	668.2	24.7
	O IV	609.832	5.21	63.8	9.1
	Mg X	624.943	6.05	327.2	12.1
	O V	629.730	5.38	693.0	86.3
743-800	Ne VIII	770.410	5.80	137.9	8.1
	Ne VIII	780.325	5.80	74.6	4.4
	O IV	787.713	5.21	75.7	10.7
	O IV	790.203	5.21	139.8	19.9

Intensity ratios will be used to derive physical parameters of the emitting plasma, e.g., electron temperature and density. Integrated intensities will be used to derive the emission measure distribution. Density diagnostics will be used to obtain the filling factor in coronal loops.

Physical parameters, derived from NEXUS data, will drive state-of-the-art coronal modeling. Drs. A. Poland and J. Mariska will construct new energy balance models to evaluate the effect of the observed velocity structure on coronal loop emission. Details of the observed time-resolved heating rate will be incorporated. New models of the ion-cyclotron wave spectrum will be constructed by Drs. L. Ofman and J. Davila, consistent with the new NEXUS observations of coronal hole line widths. The observations of CME initiation will provide a dynamic picture of the build-up and eruption of the CME at a number of different temperatures. These data will be compared with 3D magnetohydrodynamic (MHD) simulations led by Drs. S. Antiochos and J. Klimchuk to provide new knowledge of the entire CME process. Full disk images will be analyzed and used to improve the NRLEUV model by J. Mariska.

D.4 Minimum Mission

The flexible observational capability of NEXUS permits a "graceful degradation" of science return if a descope from the Baseline to the Minimum Mission (MM) becomes necessary. For the MM, the NEXUS Baseline requirements are modified in two ways; (1) the overall instrument effective area is decreased by a factor of 2 from 172 to 86 mm^2 at 600 A (still ~10X larger than Coronal Diagnostic Spectrometer (CDS) and ~3X larger than EIS), and (2) the number of CMEs observed is reduced from 40 to 20 during the mission. Decreased effective area reduces instrument and mission schedule risk during development, and thereby controls cost growth by providing options which could be exercised if there are problems with mass, optical coatings, grating efficiencies, etc. Reduced operations during the MO&DA period simply reduce cost. These and other descope options are discussed in Section F.3.a.

The reduced effective area of the MM doubles the exposure time for NEXUS, reducing the temporal resolution of the instrument. This has very little effect on the quality of the data for EUV irradiance measurement, but would degrade the capability of NEXUS for observing the heating mechanism in coronal loops, for measuring line profiles in the solar wind acceleration region, and for understanding the dynamics of CME initiation. There are three key points for understanding the graceful degradation of NEXUS: (1) there are no hard "break points" for NEXUS science return, (2) the loss of effective area can be compensated to some extent by reducing the rastered FOV or reducing the spatial resolution, and (3) the accuracy of the Doppler velocity and line intensity measurements are preserved in all cases. This allows NEXUS to maintain a high quality investigation of solar dynamics, still about an order of magnitude better than its predecessors, even in the MM.

Reducing the number of CMEs observed during the mission from 40 to 20 decreases the number of observing days required to meet the NEXUS science objectives from 567 to 334. Even accounting for eclipse season, NEXUS would accomplish all reduced science objectives with just over a year of science operations, dramatically reducing MO&DA costs for the mission.

D.5 Science Implementation

To satisfy the NEXUS science measurement requirements (Table 1), an instrument with the following new capabilities is required: (1) spatial resolution of 0.5 arcsec/pixel, (2) velocity resolution ≤2 km/s, (3) instantaneous temperature range of 0.02-15 MK, (4) instrument effective area ≥150 mm^2, and (5) FOV >1 solar radius.

The NEXUS optical design (Foldout 2H) is the latest in a series of two element imaging EUV spectrographs using toroidal gratings, which include SERTS, CDS/SOHO and EIS/Solar-B. The instrument obtains imaged spectra with high spectral, spatial, and temporal resolution over a large spatial field with nearly a full grating order of simultaneous wavelength coverage. The two optical element design simplifies the instrument and maximizes instrument throughput/cadence.

D.5.a Instrumentation

The instrument consists of an off-axis paraboloid telescope of modest aperture followed by a toroidal, variable-line-space (TVLS) single grating spectrograph. An optical layout showing the instrument concept and subassembly placement is presented in Foldout 2. Nominal instrument characteristics are given in Foldout 3. Both optical elements are coated with high-reflectance, broadband B_4C/Ir coatings. The telescope forms a real image of the solar disk at the position of a slit assembly containing several interchangeable slits and one slot. The mirror is articulated in pitch and yaw to raster the entire disk and corona out to 2.5 Rsun. This same mechanism adjusts the NEXUS internal pointing to correct residual S/C jitter. Error signals are provided by an externally mounted electronic boresight. After passing through the slit, the EUV radiation is dispersed and reimaged by a TVLS grating onto three passively cooled, solar blind, intensified CCD detectors. A mechanism is incorporated into the grating mount to allow in-flight adjustment of the spectrograph focus. The optics, mechanisms, and detectors are housed and mounted in a rigorously cleaned, aluminum structure/optical bench.

The NEXUS instrument will be developed using a protoflight approach. Development risk will be reduced by also developing and testing instrument component Engineering Model (EM) hardware where appropriate. EM electronic components will be integrated for end-to-end testing, while the structure and mechanisms EMs will undergo vibration testing. Table 4 in Section D.5.a.8 provides additional details regarding planned tests utilizing the EM hardware.

D.5.a.1 Optical Design

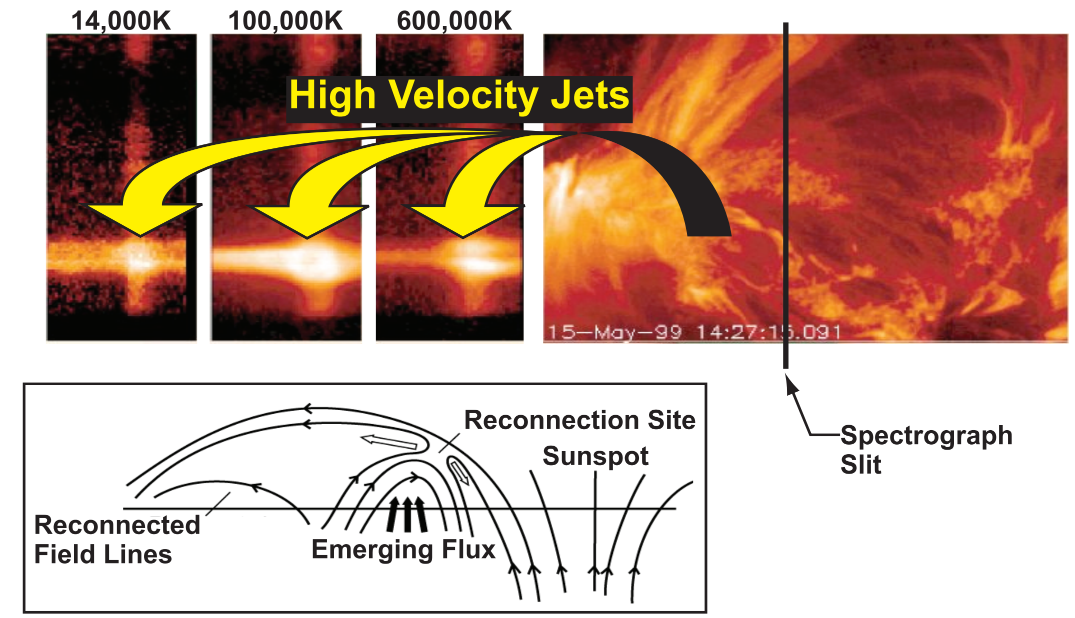
Technical specifications for the NEXUS optical design are given in Foldout 3F, G, and H. The primary mirror was over-sized to provide 20% more effective area than the Baseline Mission requires to provide margin for fabrication of the optics. Imaging performance is excellent across the usable wavelength range over the entire slit, Foldout 3B. The extent of the combined telescope/spectrograph spot sizes are less than or comparable to the pixel size over the FOV and wavelength range of the instrument.

The surface quality specifications of the primary mirror are defined to assure that scattered light requirements for the off-limb observations are met. Surface specifications (Foldout 3F) are very similar to the mirrors procured for Solar-B and FUSE. The baseline material for the substrate is low coefficient of thermal expansion Zerodur.

The grating (Foldout 3H) is ruled onto a toroidal surface like that used in many prior solar EUV spectrographs including SOHO/CDS,

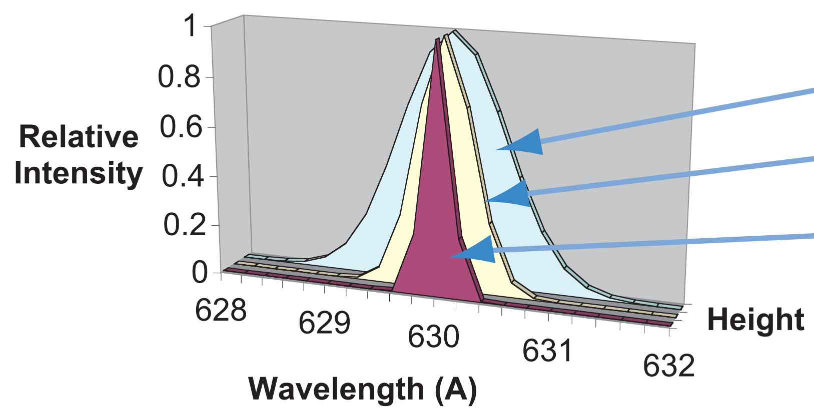
NEXUS Science Objectives

A How are coronal loops heated?



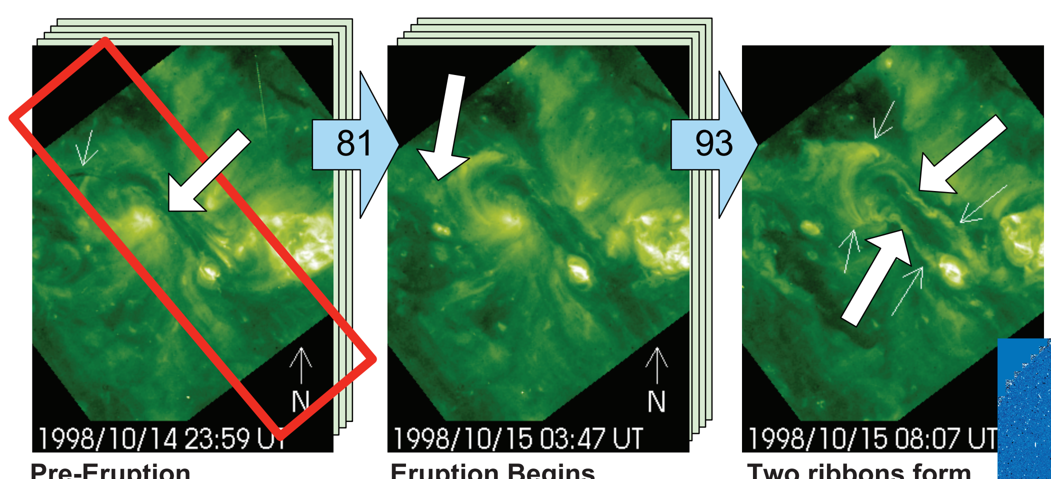
NEXUS will provide the dynamics information required to discriminate between competing loop heating mechanisms, and identify reconnection sites.

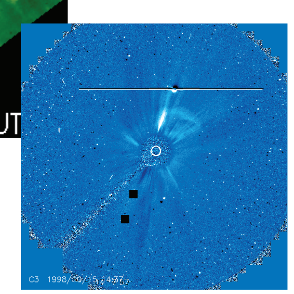
B How and where is the solar wind accelerated?



NEXUS will provide the definitive test of ion cyclotron heating. The width of O V is expected to increase dramatically between 1.5-2 Rsun.

C What initiates coronal mass ejections and other coronal transients?



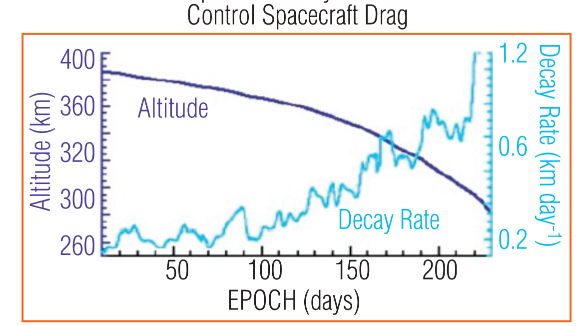


Associated LASCO CME

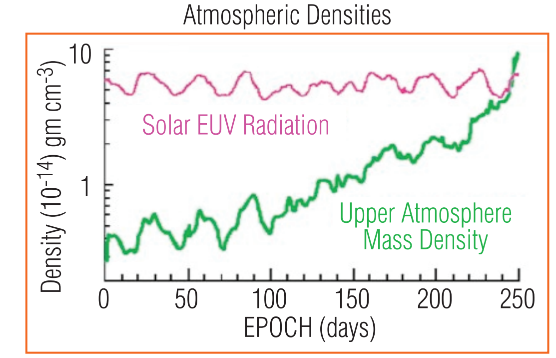
NEXUS has sufficient spatial and temporal resolution to resolve the CME initiation process. This series of EIT images shows the development of a large CME. Red rectangle shows NEXUS FOV and blue arrows show the number of additional NEXUS rasters between images.

D What are the sources of solar ultraviolet irradiance variations?

Atmospheric Density Fluctuations Control Spacecraft Drag



EUV Fluctuations Alter Atmospheric Densities



EUV irradiance drives the structure of the upper atmosphere of Earth.

NEXUS will provide the scientific foundation for the development of tools to predict space weather.

Solar-B/EIS, and the sounding rockets SERTS and EUNIS. However, instead of the classical toroidal uniform line-spaced grating, NEXUS uses rulings with varied line-spacing of a form recently developed by Kita, Harada, and collaborators. Such spectrographs, involving spherical varied line-space (SVLS) gratings, have now been successfully flown on several astronomical satellite missions (e.g., EUVE[46] and ORFEUS[47]). The NEXUS design combines these previous concepts, for the first time in an orbital instrument, by using a TVLS grating. Four vendors (Diffraction Products, Hitachi, Jobin-Yvon, and Zeiss,) have indicated that they can provide the TVLS grating for NEXUS by responding with offers to our Request for Bids for the fabrication of this design.

Our baseline procurement plan is to order TVLS gratings from two different vendors early in the program. A set of SVLS gratings will also be procured to serve as a back-up in the unlikely event that the TVLS gratings do not meet specifications. Use of the SVLS grating would result in some loss of performance, but would still satisfy all minimum mission success criteria.

Three slits, 0.5, 1.0, 2.0 arcsec wide x 16 arcmin long, and a slot 1 arcmin wide x 16 arcmin long, are required for NEXUS. Slits will be fabricated from a single crystal silicon wafer using the procedures successfully developed for the GSFC SERTS suborbital program.

The coatings developed[48] for NEXUS consist of 60 A of B_4C deposited onto a 100 A coating of Ir. The measured coating performance compared to SiC is plotted in Foldout 3E, showing its enhanced response at the shortest wavelengths observed. In terms of chemical resistance and hardness, B_4C has properties similar to diamond. B_4C coatings have shown good aging properties[49], better than SiC. B_4C has proven to be a robust material that can withstand exposure to atomic oxygen in low-earth orbit[50].

NEXUS is equipped with a biaxial tilt mechanism on its primary mirror and a focus mechanism on the grating; the degrees of freedom allowed by these mechanisms relax the initial alignment requirements on the instrument optics. Fiducialization of all of the optics will be performed during characterization to allow placement of each element within the optical bench in six degrees of freedom. An end-to-end imaging error budget, Foldout 3A, has been developed, with allocations that are achievable. No new optical technology is required for NEXUS.

D.5.a.2 Instrument Electronics

The instrument consists of the Main Electronics Box (MEB), the detector assembly, and the electronic boresight, Figure 4. The MEB controls all of the instrument functions including the mechanisms, the scan mirror, and temperature. The MEB boards are exact copies or closely resemble flight boards present in the SECCHI design; the MEB electronics is being delivered by the Naval Research Laboratory (NRL).

The MEB interfaces the S/C to 3 independent detectors. Each consists of an intensified CCD, a controlled high voltage power supply, and read out electronics. The detector assembly

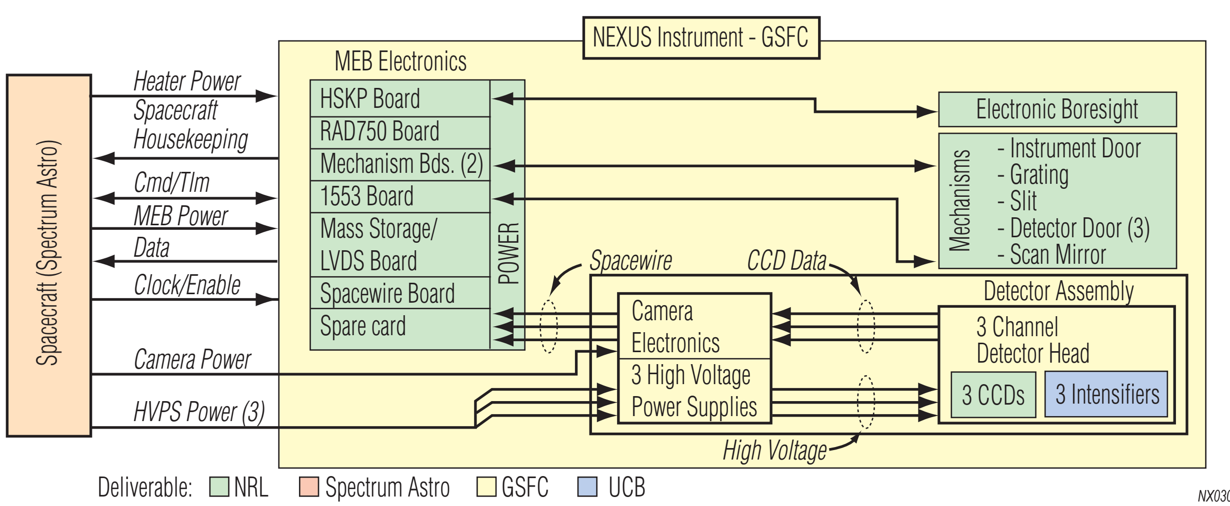


Figure 4: Electrical Block Diagram—NEXUS uses open architecture interface standards.

is similar in design and function to SECCHI and others. It will be delivered by GSFC with heritage CCDs supplied by the NRL.

D.5.a.2.1 Detector Assembly

The NEXUS design requires three independent identical Intensified CCD (ICCD) detectors operating as analog integrating cameras using proven flight designs. The performance characteristics are listed in Foldout 3I. A schematic of one of these units is shown in Foldout 2A.

The active area of the image intensifier is square, 34.82 x 34.82 mm (Figure 5). An incident photon strikes the photocathode deposited on the front of an MCP, generating a photoelectron. The detectors will have KBr photocathodes, Foldout 3C. The NEXUS MCP has 5 μm pores on 6 μm centers, and each pore has an L/D of 110:1. An emitted photo-electron generates an avalanche of secondary electrons that are accelerated by the potential applied across the MCP. At the back of the MCP a large number of electrons exit the pore for each detected photon. This is controlled by ~1200 V (software adjustable) applied across the MCP, and will be chosen to optimize the dynamic range and sensitivity of the detector. The output of the MCP is proximity focused onto an aluminized phosphor screen deposited on the output fiber optic window. A voltage of ~4000 V is applied across this gap (~0.5 mm) to minimize spreading of the electron cloud before it strikes the screen. This produces an analog visible light copy of the incident EUV illumination which is then read out using a conventional CCD. A fiber optic taper (1.26:1) reduces the size of the square image to 27.65 mm on a side to map the 17 μm focal plane pixels into 13.5 μm pixels on the CCD.

Figure 5: Square intensifier similar to the NEXUS design

The front of the intensifier tube is sealed with a vacuum door. The MCPs will be scrubbed so that the MCP gain change with accumulated use is minimized. After scrubbing, the detectors are evacuated at all times to assure that the scrub is not lost, and consistent calibration is maintained. The vacuum is maintained with small ion pumps. Prior to S/C encapsulation, we will remove the external power supply for the ion pumps.

The E2V 42-40 CCD detector selected is a 2048x2048 device with 13.5 um pixels and is identical to the device flown on and selected for Rosetta and SECCHI. The CCDs will be cooled to -40˚C with a passive radiator system. This reduces the CCD dark current and minimizes the impact of radiation damage. Each CCD has a heater to permit lattice annealing. During a typical exposure, the CCD is shuttered by controlling the MCP voltage. Image data is then clocked out through two readout ports at a rate of 2 MHz for each port, giving readout time of approximately 1 s.

Following the SERTS design, the detector door will be mounted directly to the front of the intensifier. The CCD will be bonded to a fiber optic block at the back of the intensifier. To minimize mechanical loads on the assembly, a flexible thermal strap will conductively couple the back of the CCD to the radiator/aluminum bracket assembly.

Each camera will have a driver/preamp board at the CCD. This board will interface to the camera main electronics, consisting of a LVPS, programmable bias voltage board, dual channel CDS video processor and an 8051 microcontroller with a CPLD timing generator. The camera will have no onboard storage, relaying all images in real time to the NEXUS MEB via the SpaceWire interface (ESA Firewire Implementation, IEEE-1394). The camera MEB will house three independent sets of electronics for the three detector head assemblies.

The modulation transfer function (MTF) of the ICCD detector system was measured to obtain an effective pixel size of 17 μm (Foldout 3D).

The high voltage power supply provides the voltages needed to operate the image intensifier. A similar supply is operating now on the

SXI mission, and we have flown this detector four times on the SERTS program.

D.5.a.2.2 Main Electronics Box

The NEXUS Main Electronics is the principal interface and control element between the S/C and the instrument. The block diagram, Figure 4, shows the principal functions and boards. It provides command, telemetry, mass storage, scan mirror and mechanism control, and housekeeping functions. The design is implemented in an 8 slot 6U Euro-card chassis with a compact Peripheral Component Interface (PCI) back plane. A total of seven boards is envisioned, five of which are direct copies of SECCHI boards or are used in other flight programs, leaving one spare board expansion slot.

The BAE RAD 750 cPCI computer board is a flight qualified, radiation tolerant power PC that implements the instrument control and data compression functions. This board is identical to those used on SECCHI and SHARPP and numerous NASA and Air Force programs, and provides speed and processing capability exceeding the requirements of the NEXUS Mission.

The SpaceWire board is used in SECCHI and SHARPP and is the high speed data interface between the MEB and the detector assembly. It provides three 100Mbps data and control paths to the cameras and 250 Mbyte of high speed local storage accessible to both the instrument cameras and the processor.

The Housekeeping Board is used in SECCHI and SHARPP and provides multiple functions: stepping motor door control signals with drivers in the power supply unit; heater control signals, also with drivers in the power supply unit; guide telescope signals; electronic boresight sensor; and miscellaneous low voltage and thermistor measurement capability.

The 4 Gbyte memory board is an existing design from SEAKR, Inc. The board will store any combination of instrument data, telemetry data or processed data. Also, this board provides the high speed serial readout (Low Voltage Differential Signaling [LVDS] interface) whose 10 Mbps capability exceeds the 8 Mbps requirement of NEXUS. The LVDS interface is controlled by the Payload and Attitude Control Interface (PACI) board in the S/C electronics system.

Two new 6U boards will be implemented using designs from previous programs; both will employ existing cPCI FPGA designs. One contains the two axis scan mirror controller which uses two 14 bit amplified voice coil drivers and differential eddy current position sensors. The second will control the grating focus, slit/slot interchange, and the instrument door mechanisms.

The existing SECCHI low voltage power processing and distribution electronics will be used for all local 3.3v, 5v, and ±15v needs. It also contains the three detector door drivers and eight heater control switches and inrush limiting circuitry.

D.5.a.2.3 Software

The NEXUS flight software will be based upon the Triana and SECCHI/STEREO software. Since much of the NEXUS electronics trace their heritage to the SECCHI electronics, the SECCHI flight software is already a close match to the electronics and satisfies or exceeds most of the requirements for NEXUS. The SpaceWire and MIL-STD-1553 interfaces proposed for NEXUS are already supported in the SECCHI software. All of the infrastructure routines for commanding, housekeeping, health and safety, scheduling and image processing are already ported to the target BAE RAD 750 processor board and will be available for NEXUS.

The software team will concentrate on the NEXUS mission-specific software. New software tasks include data management for the large memory used as a data recorder, and development of drivers and software for NEXUS-specific instrument tasks.

Current estimates show that the NEXUS CPU and EEPROM usage are easily met. The CPU estimate is for only 8 MIPS whereas a 300 MIPS RAD 750 is available.

D.5.a.3 Mechanisms

All NEXUS mechanisms utilize heritage designs. An aperture door (Foldout 2F) maintains cleanliness of the NEXUS optical assembly. Based on aperture mechanisms successfully used for the SOHO's SUMER and LASCO telescopes, a stepper motor provides actuation of the door to 270°. Should the motor fail, a paraffin-actuated cam follower provides redundancy.

Based on the successful ASTRO UIT image motion compensation mechanism, (Foldout 2G) the NEXUS scanning mirror mechanism provides the necessary pitch and yaw articulation for rastering the solar surface and compensating for S/C jitter. The NEXUS mechanism image size, range of motion, and stability requirements (Foldout 3J) are similar to those of the UIT mechanism performance.

The mirror is kinematically attached to a platen suspended on a two-axis gimbal. Flexural pivots provide positionally stable rotation of the gimbal axes with minimal friction and hysteresis. Differential inductive transducers, combining high sensitivity and stability with excellent frequency response and linearity, measure angular position of the mirror. Linear, frictionless voice coil actuators produce torque. The mirror/platen assembly is statically balanced about the axes of rotation and requires no locking devices for launch.

The UIT design is modified slightly to fit in the available instrument volume. The flatter NEXUS design will allow a radiative cold plate to be attached to back of the mechanism and provide the cooling of the mirror, if necessary. Design work in Phase A will include repackaging this mechanism. This mechanism will be life-tested.

NEXUS science requires one of four slits to be introduced into the optical path. To achieve this, a rotary mechanism (Foldout 2B) based on the Solar-B/EIS slit mechanism is proposed. A rotary design is preferred for simplicity of operation, reliability, and predictability. This mechanism will be life-tested.

The NEXUS grating focus mechanism (Foldout 2C) is also based on a Solar-B/EIS design. It supports a 20x20 mm grating while providing ±8 mm of focus adjustment in 3 µm steps. The grating bracket is mounted to a cross roller slide and driven by a geared stepper motor. An optical encoder provides feedback for closed-loop operation. A non-backdriving ball-screw combined with the stepper motor detent provides the launch-locking function.

The NEXUS detector door mechanism (DDM) provides a vacuum tight enclosure for protection of the detectors, Foldout 2D. The door is opened for instrument observation while in vacuum and sealed for ground storage, transportation, and integration activities. The DDM/detector assemblies are installed and removed from the instrument as integral units. Originally designed and qualified for the ARGOS instrument, the DDM is simple, forgiving, reliable, and robust. It incorporates a geared stepper motor combined with a four bar linkage to achieve high clamping force. The vacuum seal is maintained with a Viton o-ring.

D.5.a.4 Spectrograph Electronic Boresight

An electronic boresight mounted on the bottom of NEXUS (Foldout 2I) provides the necessary fine-pointing solar angular measurements with respect to Sun center for the image rastering/motion compensation mechanism. The boresight is similar to those successfully flown on LASCO and as a Guide Telescope on the TRACE satellite. The requirements for the boresight are given in Table 3. International Radiation Detectors (IRD) will provide the radiation hardened[51] ultra-stable UVG-600 quadrant detectors. The removal of the field stop and installation of a "test" field stop with wider slots will allow performance testing of the system using a Sun simulator telescope under normal laboratory conditions.

D.5.a.5 Structure Description

The proposed structure (Foldout 2E) is machined from one continuous forging of Aluminum 6061-T6 to maximize structural stability and material property uniformity. The structure supports the instrument door, scanning mirror, heat rejection mirror, slit selection mechanism, grating mechanism, detector/door assemblies, camera electronics, and required radiators. Internal bulkheads provide light baffling and component mount points. Detector access is through a removable panel in the rear bulkhead. NEXUS will be mounted on a system of three flexural mounts to de-couple the instrument from S/C distortions while maintaining structural rigidity.

Preliminary analysis of the NEXUS structure with lump masses representing optical and electronics components indicates a fundamental frequency of >50 Hz. In Phase A a coupled loads analysis will be performed on the NEXUS structure assembly. In addition, a structural-thermal-optical performance (STOP) analysis will be used to predict and optimize the optical performance in the presence of structural and thermal loading conditions.

D.5.a.6 Thermal Control System

As a result of the imaging error budget in Foldout 3A, the on-orbit thermal transients for

Table 3: NEXUS boresight performance requirements

accuracy (one hour)	<1 arcsec over a 50 arcsec motion
accuracy (ten minutes)	<0.25 arcsec over a 50 arcsec motion
noise equivalent angle	<0.1 arcsec
maximum expected operating range	300 arcsec
bandwidth	updated at 50Hz
mass	<1.5kg

the NEXUS optics box must be within 1°C. In order to satisfy this requirement, the instrument will be thermally isolated from the S/C and will employ an active thermal control system using strategically-placed heaters throughout the optics box. A radiator will maintain the CCD detectors below the required temperature of -40°C. Preliminary analyses performed on a simple optics box model show that an anti-Sun viewing silver Teflon-coated radiator with a partial view of the S/C can satisfy the -40°C temperature requirement with ample margin.

The instrument high voltage power supply and MEB are mounted to the S/C upper deck. Once again, a passive thermal control system is employed for these two boxes. They are both conductively coupled to the S/C with their own respective radiators, and/or any of the following: heaters, thermostats, coatings, and thermal blankets. Standard engineering practice will be used to size radiators and heaters to ensure that these boxes and their components do not exceed their temperature requirements.

D.5.a.7 Contamination Control

The NEXUS instrument is sensitive to particulate and molecular contamination because it operates in the ultraviolet (UV) wavelength region 457-800 A. The instrument contamination control approach is a systematic application of contamination control technologies in all phases of design, fabrication, assembly, transportation, integration, test, and flight operations to assure that mission objectives are not limited or compromised by the effects of contamination.

Budgets will be established for surfaces that are inaccessible or not conducive to traditional cleaning techniques. Requirements will be based upon directly applicable flight heritage from the approach developed by GSFC for the successful TRACE program. Molecular and particulate contamination analyses will be performed to assess the contamination effects on critical surfaces, to identify requirement incompatibilities, and to help develop an effective contamination control program. An instrument total source outgassing will be analyzed using Molecular Flux (MOLEFLUX) or equivalent modeling techniques for vent paths to critical surfaces.

Contamination protective devices, such as an aperture cover, Electrostatic Discharge (ESD) bags, and purging, will be implemented to reduce contamination risk to the sensitive components. Material screening will employ ASTM E595 as a minimum and ASTM E1559 for critical applications where depositions are dependent upon various source and receiver temperatures below the ASTM E595 criteria.

D.5.a.8 Integration and Verification

The NEXUS instrument will undergo a thorough functional, performance, and environmental test program prior to integration with the S/C. The integration and test flow is depicted in Figure 6. The preliminary verification matrix is shown in Table 4. A S/C simulator will be developed to verify the

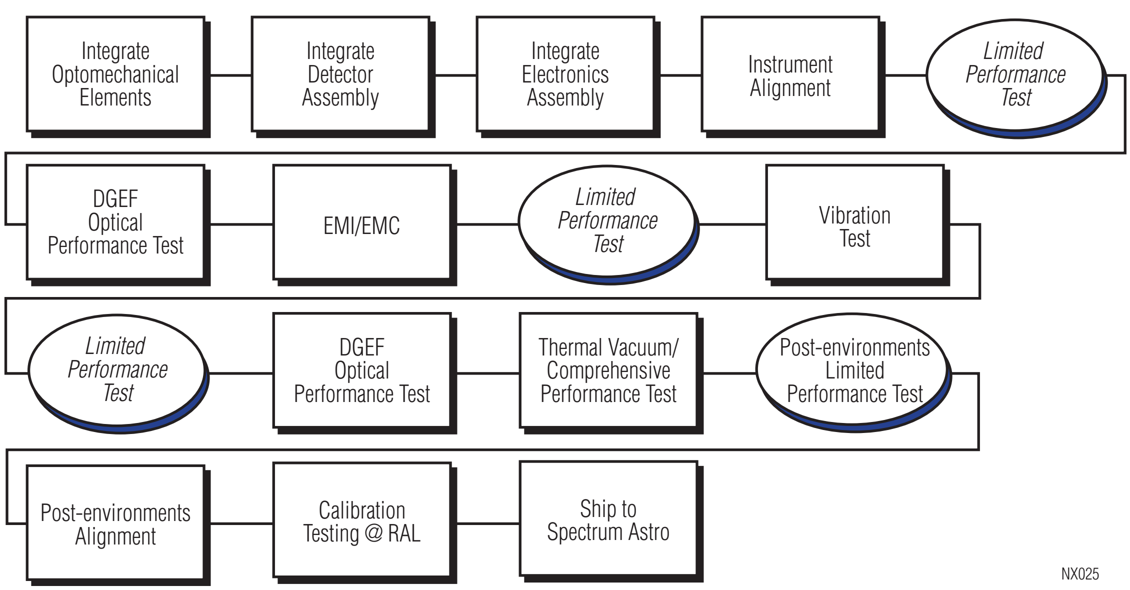


Figure 6: The NEXUS instrument I&T flow will be accomplished using existing GSFC and RAL facilities.

Table 4: NEXUS Verification Matrix—NEXUS will undergo a complete environmental test program. Tests marked E are done on the Engineering Model, and tests marked F are done on the Prototflight Model.

	Item	Inspection	Optical Testing/ Alignment	Vibration Testing	T/V Testing	Functional Testing	LPT/ CPT	Life Test
Components	Slits	E,F						
	Grating	E,F	F					
	Mirror	E,F	F					
	Structural and mechanical parts	E,F						
	Actuators	E,F				E,F		
	Electronic parts	E,F						
Sub-assemblies	Front door					F	F	
	Electronic boresight		E,F	E,F	E,F	E,F	E,F	
	Scanning mirror mechanism		E,F	E		E,F	E,F	E
	Slit/slot interchange mechanism (engineering model)		E,F	E		E,F	E,F	E
	Grating focus mechanism		F			F	F	
	Breadboarded circuit cards, etc.					E	E	
	Main electronics box			F	F	E,F	E,F	
	High voltage power supply			F	F	E,F	E,F	
	Camera readout electronics box			F	F	E,F	E,F	
	ICCD detector head		E,F		E,F	E,F	E,F	
Models	Proto-flight model instrument		F	F	F	F	F	

spacecraft-to-instrument interface during the integration process. In addition, the engineering model instrument electronics suite will be provided to Spectrum Astro for integration with the Hot Bench.

Optical verification of the instrument in the extreme ultraviolet will be performed in the Diffraction Grating Evaluation Facility at GSFC. Limited and comprehensive performance test procedures will be developed to test the functional and performance capabilities of the instrument. Prior to delivery of the instrument to Spectrum Astro, the instrument will undergo radiometric calibration at RAL in their extreme ultraviolet calibration facility.

D.5.a.9 Radiometric Calibration

Component efficiencies will be measured at the NRL beamline on the Brookhaven synchrotron. Preflight calibration will be carried out in an existing specialized facility at the RAL, which has already been used to do similar calibrations of CDS and SERTS, as well as being scheduled for EIS and EUNIS.

During the Mission, we will track the absolute response of NEXUS by cross-calibration against experiments onboard SOHO (CDS & SUMER) and on SDO (SHARPP & EVE), as well as any other suitable solar EUV instruments (such as SORCE) operating at that time.

On-orbit detector flat-field response changes will be monitored by placing the slot in the focal plane and then moving the solar image at the slit in small increments while taking repeated exposures.

The NEXUS team will collaborate with sounding rocket flights to update the instrument calibration in flight whenever possible.

D.5.b Mission Concept

The NEXUS observatory will collect data on a nearly continuous basis. Long duration, high-cadence observations that follow large-scale solar features such as active regions, filaments, and coronal holes will be combined with synoptic (4/day) full Sun rasters in a daily science plan. The basic observing strategy will be to choose a suitable region, based on publicly-available magnetograms, and observe it for a pre-determined period of time. No real-time commanding is required. A typical observing day is shown in Table 5.

Observational modes are determined by slit, exposure time, line list, and raster size selection. Mission commanding will occur during communications contacts through a single

Table 5: Typical Observing Day—NEXUS was planned with a robust ground system, with two unused passes/day and an 8 Mbps capability (6.2 Mbps requirement) to provide margin for commanding or data downlink. Ground contact times and durations used in this example were calculated using Satellite Tool Kit™.

Science Objective				Start Time [UT]	Stop Time [UT]	DataGen Rate [kbps]	On-Board Stored Data [Gbit]	Observing Mode	
a	b	c	d					ID	Description
--	--	--	--	21:26:32	21:36:30	0	0.00	-	Downlink pass complete
X		X	X	21:36:30	3:36:30	333	7.21	3	AR 1"x16'x4' raster A1
			X	3:36:30	4:0:24	125	7.39	44	2" full disk slot raster Q5
X		X	X	4:0:24	4:52:28	617	9.32	10	AR 0.5" Slot Raster A4
--	--	--	--	4:52:28	5:2:1	-8000	4.74	-	1st Downlink Pass
X		X	X	5:2:1	6:47:26	34	4.95	23	QS 1" Slit Raster Q2
--	--	--	--	6:47:26	6:59:18	-8000	0.00	-	2nd Downlink Pass
X		X	X	6:59:18	8:25:28	50	0.26	19	QS 1"x16'x1' Raster Q1
--	--	--	--	8:25:28	8:34:13	--	0.26	-	3rd Downlink Pass (Margin)
X		X	X	8:25:28	12:60:28	50	1.08	19	QS 1"x16'x1' Raster Q1
			X	12:60:28	12:11:22	189	0.53	41	2" Full Disk Slot Raster Q4
X		X	X	12:11:22	18:27:16	50	1.65	19	QS 1"x16'x1' Raster Q1
--	--	--	--	18:27:16	18:36:15	--	1.65	-	4th Downlink Pass (Margin)
			X	18:27:16	18:51:10	125	1.83	44	2" Full Disk Slot Raster Q5
X		X	X	18:36:15	20:2:15	50	2.09	19	QS 1"x16'x1' Raster Q1
--	--	--	--	20:2:15	20:14:7	-8000	0.00	-	5th Downlink Pass
X		X	X	20:14:7	21:38:41	389	1.97	7	AR 1"x16'x4' Slit Raster A2
--	--	--	--	21:38:41	21:48:4	-8000	0.00	-	6th Downlink Pass

ground station at RAL. Stored observation sequences will be loaded into command tables to provide autonomous data collection between contacts. The command file will be prepared at the GSFC SOC and transferred to RAL typically before noon (US Eastern time). Mission commanding will occur during the dusk (UK local time) communication contacts. If these deadlines are missed, NEXUS will continue with a default program until it is commanded during the dawn (UK local time) passes approximately 10-12 hrs later. During contacts, stored instrument data and observatory housekeeping data will be transmitted. Instrument and S/C housekeeping along with a small subset of imaging data will be transferred to the MOC in real time over a dedicated T1 line to monitor observatory health and safety.

D.5.c Data Analysis

Data Reformatting: In a typical day, 15 Gbit of NEXUS scientific telemetry will be received at the SOC. Immediately on receipt, these data will be reformatted into scientifically useful, Level-0 FITS-format files; FITS is a standard in the solar physics and astrophysics communities, and is supported by the National Space Science Data Center (NSSDC). The Level-0 files will include sufficient metadata derived from S/C attitude and ephemeris to allow a scientist using the data to account for the roll orientation of the spectrograph slit and the (x, y) position(s) of the slit on the Sun. Wherever possible, we will use the same metadata keywords as used in SOHO CDS and Solar-B EIS FITS files, to facilitate use of the data with existing software libraries. We expect the NEXUS Level-0 FITS files to be available online within 2 hours after receipt at the SOC.

Within 1 year of the end of the nominal mission, we will add to the NEXUS archive (discussed below) absolutely calibrated, Level-1 FITS files with corrections for detector background, flat field, throughput variations, and other instrumental effects. This “final” version of the data will prevent the calibration and correction information from becoming inaccessible due to software obsolescence.

Data Access: During the mission lifetime, the Level-0 FITS files as well as databases containing radiometric calibration and instrumental corrections (e.g., detector background, flat field, and throughput) will be archived at the SOC and will be accessible over the Internet via anonymous file transfer and the Web. Disaster recovery copies of the NEXUS database, which will total slightly over 1 Tbyte, will be stored off site, and the archive will be mirrored to Co-Investigator sites (e.g., NRL and RAL). The daily data volume is small enough that such mirroring can be achieved over the Internet.

Web access to the data will draw on the heritage of SOHO EIT and TRACE data services currently operated by NEXUS Co-Investigators. The current model for accessing "active mission" scientific data involves depositing the data in a physically centralized, active mission data archive such as the Solar Data Analysis Center (SDAC). SDAC may be replaced before the NEXUS launch date by a distributed architecture, the Virtual Solar Observatory (VSO), which will logically link Principal Investigator sites. We will provide network access to the data that is compatible with both direct, end-user initiated requests and requests routed via the VSO.

We will also provide NEXUS-specific additions to the SolarSoft library of data reduction and analysis routines written in the Interactive Data Language (IDL) to facilitate use of the data. As with the rest of SolarSoft, that software will be freely and publicly available for download. In addition, we will provide a publicly accessible catalog of the observations, including information on collaborations with other observatories.

Long-term Archiving: When the Level-1 data are produced, we will export them and supporting software and documentation to the long-term repository designated by the NEXUS Program Scientist at NASA Headquarters, in accordance with the stated policy of the Office of Space Science (OSS). We expect that repository to be the NSSDC, and will seek the assistance of NSSDC personnel in writing the NEXUS Project Data Management Plan to assure both full access to the data during the mission and continued accessibility after its successful completion.

D.5.d Science Team

NEXUS was designed by a highly experienced science team, Table 6, with a history of successful development of instruments for spaceflight, analysis of spectroscopic data to produce new scientific results, and demonstrated expertise in solar data analysis and theoretical and numerical modeling of the Sun-Earth system. All team members are partially supported by NASA funding, except for Collaborating Scientists who provide no deliverable items, and Co-Is at RAL. The solar physics group at GSFC, the Principal Investigator (PI) institution, has flight experience on the SERTS rocket, the CDS and SUMER instruments on SOHO, and more recently the EIS spectrograph on Solar-B and COR1 for STEREO, both in collaboration with the NRL. The solar group at NRL is currently actively involved in EIS on Solar-B and SECCHI on STEREO, and in the past they have produced LASCO and EIT on SOHO, and the HRTS and VAULT sounding rockets. Dr. O. Siegmund from the University of California at Berkeley, Space Science Laboratory (SSL), is a world leader in the development of image intensifiers, and will collaborate on the detector development, and the RAL will provide use of its ground station. RAL has previous ground station experience on Ariel V and VI, ACE, and as the primary ground station on IRAS. The RAL ground station is currently being upgraded to receive X-band STEREO data. The new X-band capability will be operational prior to the launch of NEXUS.

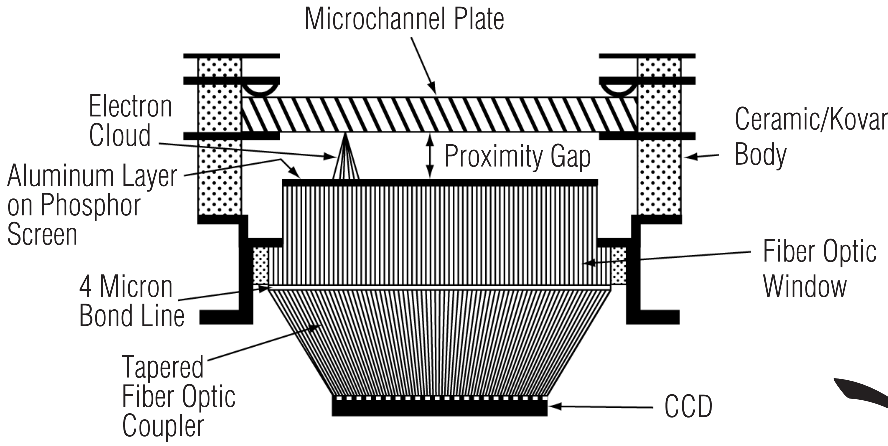
Table 6: The NEXUS Science Team has a broad range of flight instrument experience.

	Name	Title	Responsibility	Experience
GSFC	Joseph M. Davila	Principal Investigator,	All aspects of the NEXUS development & science investigation	STEREO Project Scientist, SECCHI Co-I, SERTS PI
			Co-Investigators	
GSFC	Joseph Gurman	Data Center Scientist	Develop science operations center, data archiving, & data distribution system	SOHO Project Scientist, SMM, SDAC
GSFC	Therese Kucera	Data Anal., EPO Scientist	Implementation of EPO program & data analysis	SOHO EPO, Data Analysis
GSFC	Arthur Poland	GSFC Program Scientist	Advise PI on scientific trades, data analysis	SOHO Project Scientist
GSFC	Douglas Rabin	GSFC Project Scientist	Assist PI with scientific oversight of mission in all phases	EUNIS PI
GSFC	O. C. St. Cyr	MOC Scientist	Develop mission operations center, ground station development, data analysis	LWS Project Scientist, SOHO Ops. Development
GSFC	Roger J. Thomas	Optical Scientist	Optical design, procurement support, alignment support, data analysis	CDS, SUMER, SERTS, EUNIS Co-I
GSFC	Barbara Thompson	Data Analysis Scientist	Data anal., coordination with SDO instruments	SDO Project Scientist
USRA	Scott McIntosh	Data Analysis Scientist	Data analysis, dynamic & wave effects	SUMER Data Analysis
CUA	Jeffrey Brosius	EPO, Data Anal. Scientist	Implementation of EPO program & data anal. Radio Obs. Coordinator	SERTS, VLA Data Analysis
CUA	Leon Ofman	Theory, Numerical Analyst	Solar wind & coronal loop modes to compare with observations	Solar Wind, Corona Theory
NRL	Spiro Antiochos	Theory, Numerical Analyst	Reconnection models of CME eruptions to compare with observations	A leading researcher in reconnection theory
NRL	Charles Brown	Hardware Dev. & Test	Implement development of mechanical components at NRL	LASCO, Solar-B, Yohkoh, & other programs
NRL	Kenneth Dere	NRL Project Scientist	Advise PI on scientific trades, Lead NRL scientist	LASCO, EIT, Skylab Data Anal.
NRL	James Klimchuk	Coronal Theorist	CME & Coronal loop model comparison with observations	A leading researcher in coronal loop theory
NRL	Clarence Korendyke	NRL Lead Instrument Scientist	Lead scientist for NRL hardware contributions for NEXUS	LASCO Co-I, VAULT PI, Solar-B Co-I
NRL	Enrico Landi	Spectral Theorist	Spectral modeling & data analysis	SUMER, CDS data analysis
NRL	John Mariska	Data Anal. Lead Scientist	Lead development of planning & archiving tool based on CDS/Solar-B software	Yohkoh Co-I, Solar-B Co-I
NRL	Daniel Moses	CCD Scientist	Spec, purchase & acceptance testing of NEXUS CCDs	SECCHI Co-I, SHARPP Co-I
NRL	John Seely	Optical Component Test	Conduct grating & mirror testing at the NRL Brookhaven facility	Solar-B, Yohkoh, & other EUV instruments
NRL	Harry Warren	Data Analysis Scientist	CME & Coronal loop model comparison with observations	TRACE, Yohkoh Data Anal.
NRL	Amy Winebarger	Data Analysis Scientist	CME & Coronal loop model comparison with observations	TRACE, Yohkoh Data Anal.
RAL	Richard Harrison	RAL Lead Scientist	Lead RAL scientist, data analysis	CDS PI,
RAL	James Lang	Calibration Scientist	Lead pre-flight calibration, data analysis	CDS Co-I, Solar-B Co-I
RAL	David Pike	Data Analysis Software Scientist	Develop planning & archiving tool software based on CDS/Solar-B software	CDS Co-I, Solar-B Co-I
UCB	Oswald Siegmund	Detector Scientist	Intensifier Assembly	SERTS, CDS, SUMER
			Collaborator	
GSFC	Stuart Jordan	Spectral Modeling	He emission line formation, radiation transfer	SERTS Co-I, Solar Branch Head, SOT Project Scientist

NEXUS Instrument Opto-Mechanical Layout

A Intensified CCD Assembly

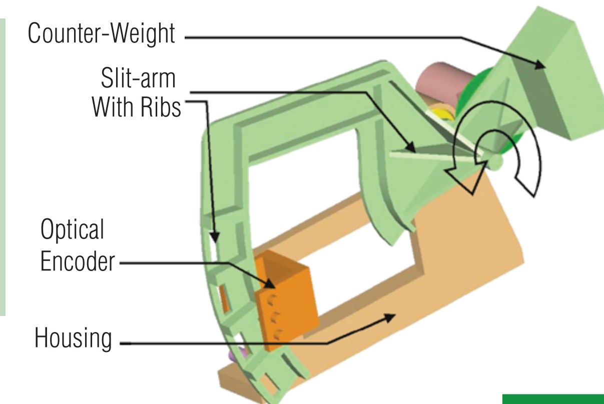
Detectors utilize a CCD to read the analog visible light image from the back of the intensifier. This approach has been successfully demonstrated on CDS, SXI, and SERTS



GSFC

B Slit Exchange Assembly

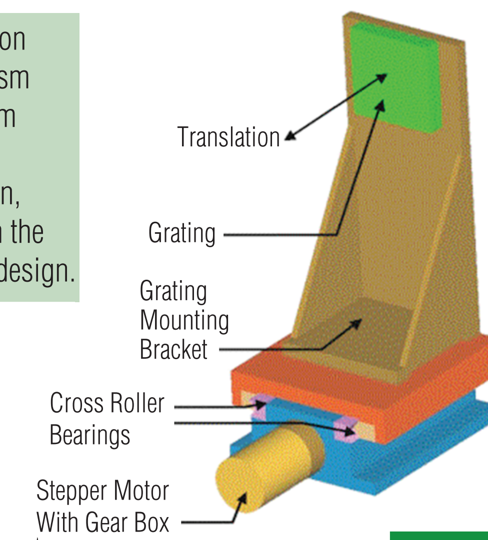
A simple counter-weighted mechanism based on the Solar-B design.



NRL

C Grating Focus Assembly

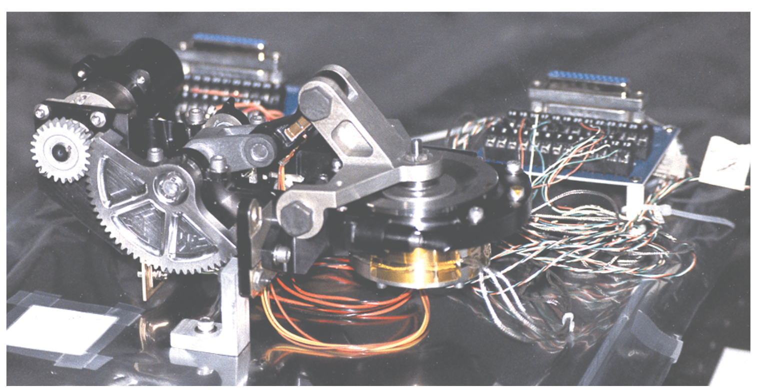
Translation mechanism with 3 µm focus resolution, based on the Solar-B design.



NRL

D Detector Door Assembly

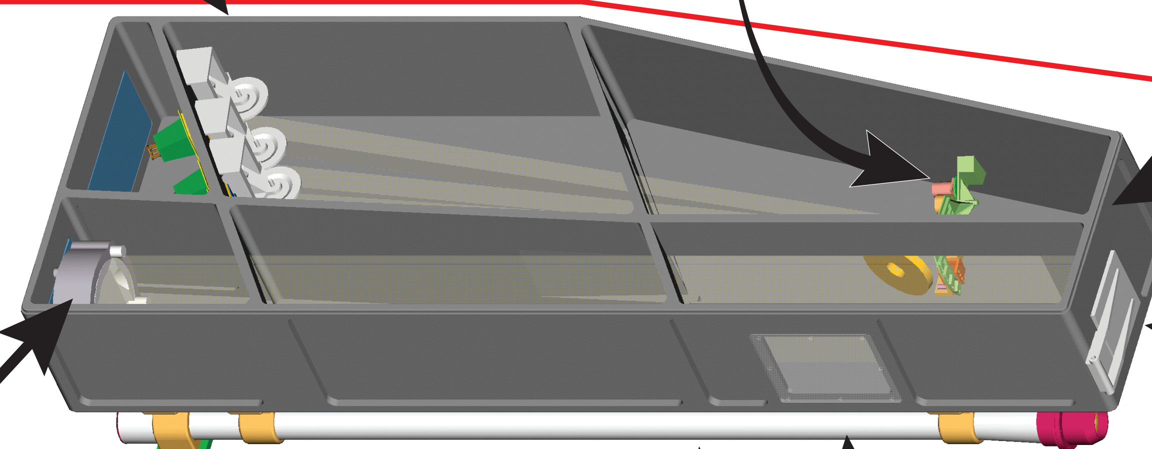
Provides vacuum tight enclosure to maintain detector calibration prior to launch similar to ARGOS mechanism.



NRL

E Structure

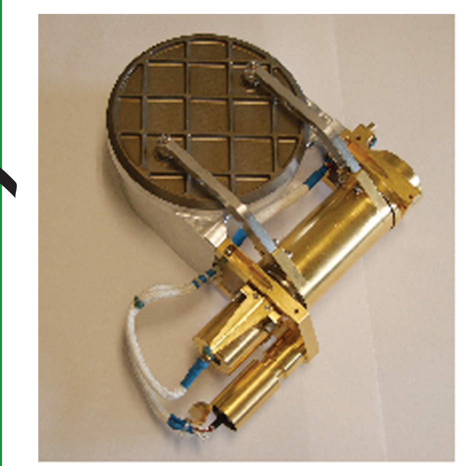
A single aluminum forging will be machined to provide all mounting interfaces for instrument components.



GSFC

F Door Mechanism

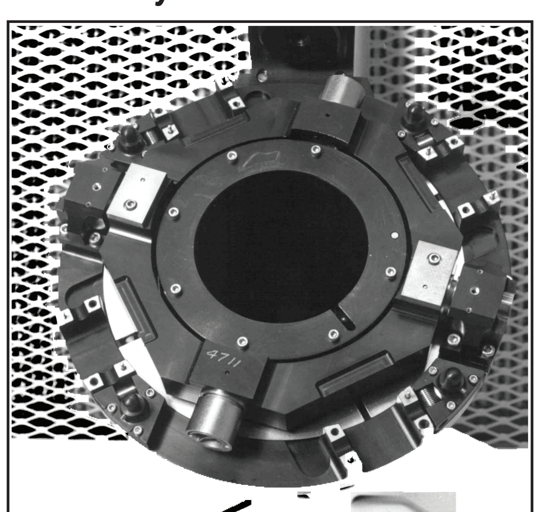
Heritage design based on LASCO & SECCHI door.



NRL

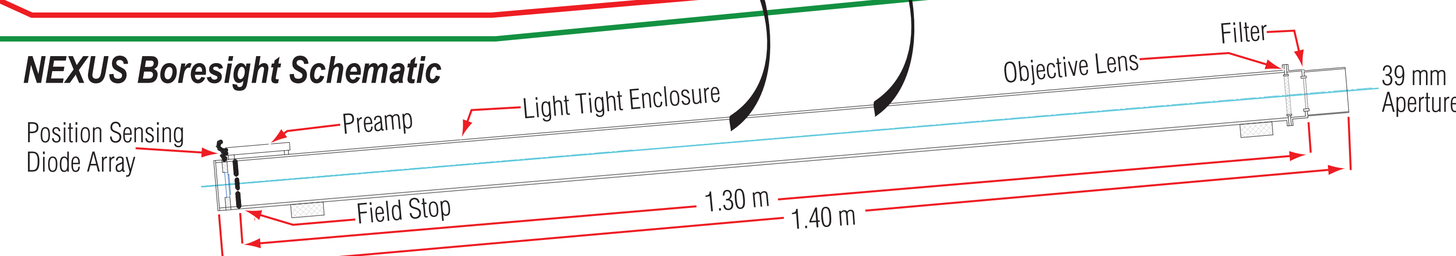
G Scan Mirror Assembly

A mechanism similar to the one required for NEXUS was built for UIT. NEXUS will use similar approach.



NRL

I NEXUS Boresight Schematic

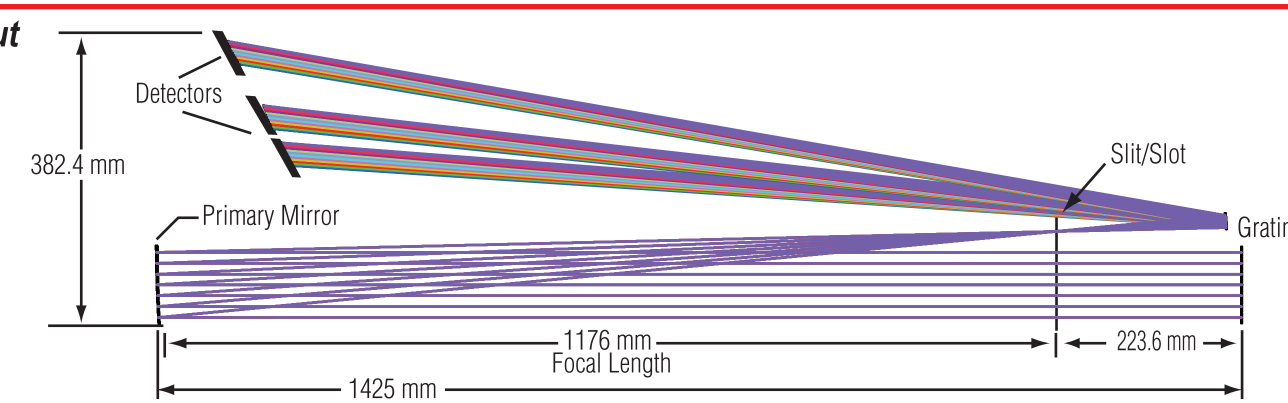


NRL

Like TRACE and SHARPP a single lens images the solar disk onto a position sensitive diode.

H Optical Layout

A 2-element reflecting optical design provides 0.5 arcsec spatial imaging and large effective area on 3 detectors.



GSFC

See Also:

D.5.a.2.1	Detector Assembly
D.5.a.2.2	Main Electronics Box
D.5.a.6	Thermal Control Sys.

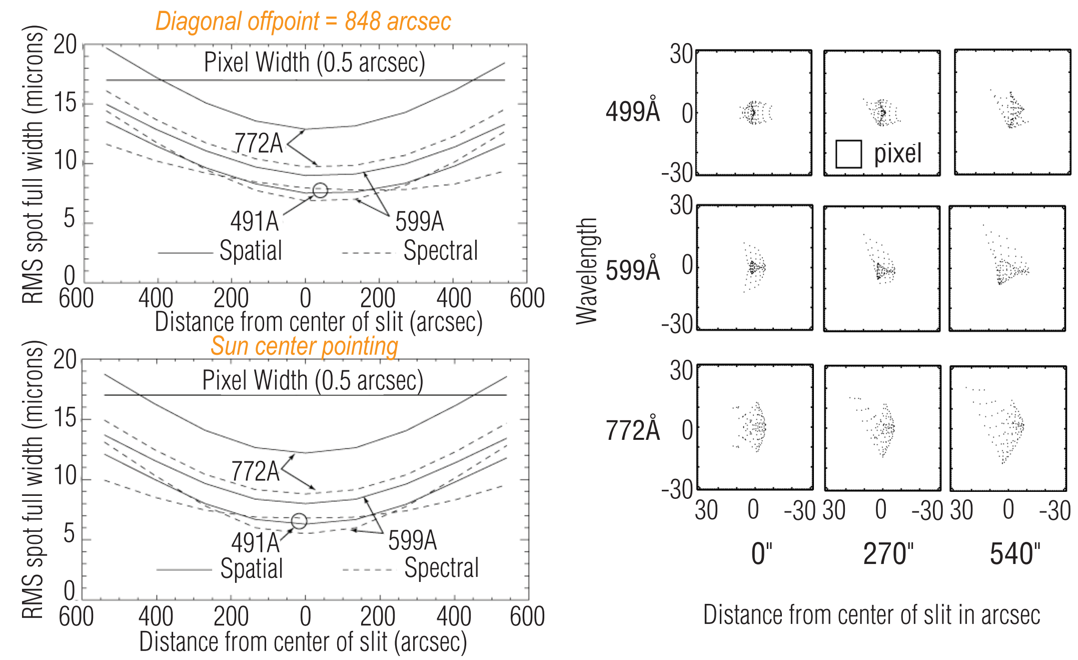
NEXUS Instrument Performance

A NEXUS Imaging Error Budget

	Contribution (µm)
Design RMS spot size	8.00
Alignment contribution	3.70
Fabrication contribution	5.09
Environmental/Launch errors	3.30
Stability (Jitter) errors	2.47
S/C Jitter correction	8.90
Total Expected RMS spot size	**14.13**
Requirement	**17.00**
Margin (RSS)	**9.45**

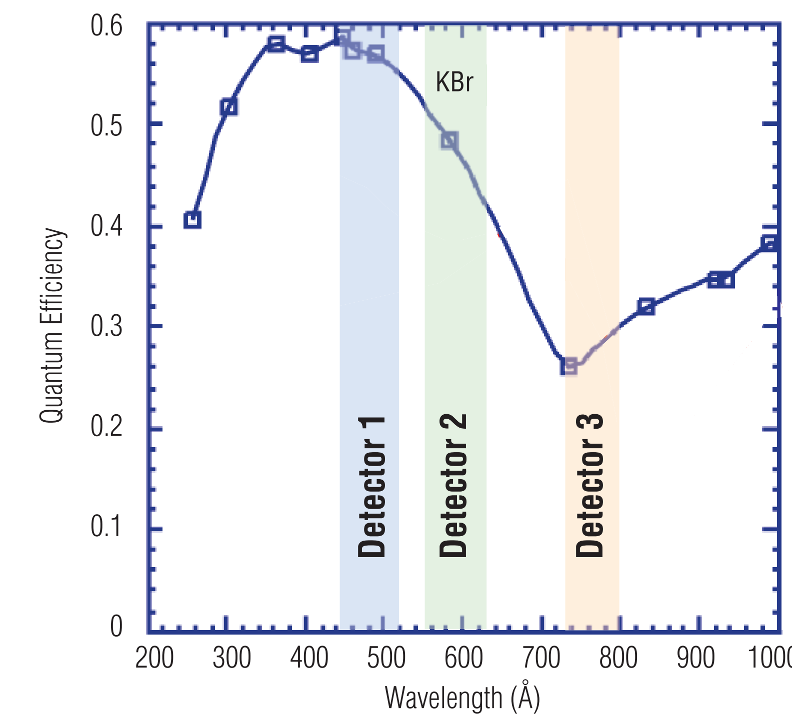
B Combined Telescope/ Spectrometer Optical Performance

The NEXUS optical design provides 0.5 arcsec imaging over the entire 16 arcmin FOV for all but the longest wavelengths.



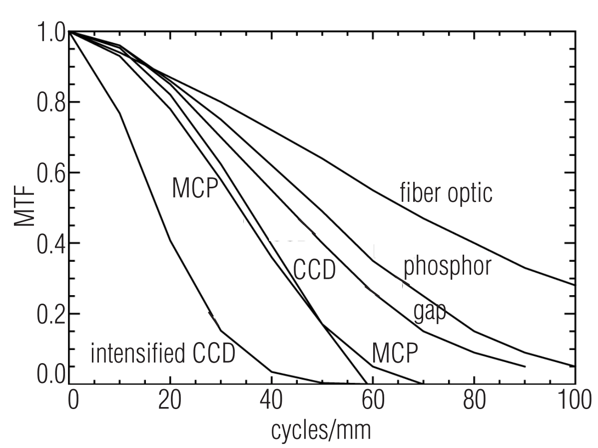
C Measured Photocathode Quantum Efficiency

KBr Photocathode provides excellent efficiency for all 3 NEXUS bandpasses.



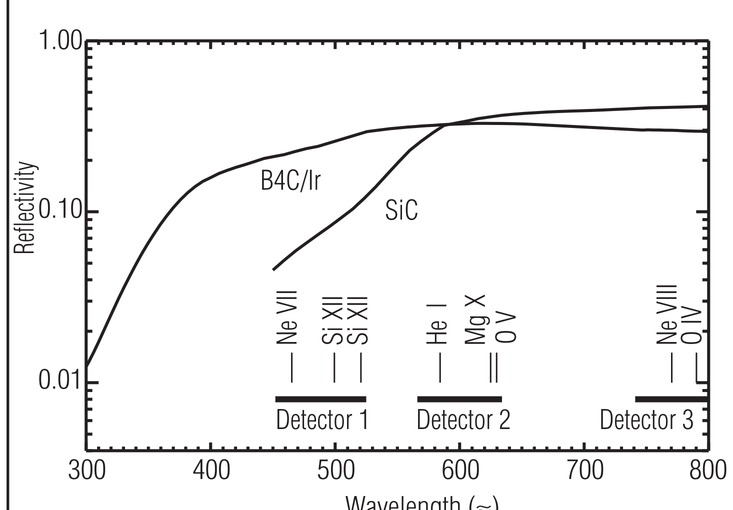
D Detector Imaging Capability

High resolution intensifier provides 17mm equivalent pixel resolution.



E Coating Reflectivity

B_4C/Ir coating is efficient and rugged.



F Telescope Optical Characteristics

Type: Single Off-axis parabola	
Mirror Clear Aperture (Diameter)	124 mm
Mirror size (Diameter)	134 mm
Focal length	1176 mm
Mirror center to parabola vertex	70 mm
Material	Zerodur
Aspect Ratio (Dia/Thick)	6:1
Plate Scale at Slit	5.7 µm/arcsec
Image Quality	< 1 arcsec
RMS Figure Error	65A
RMS Mid-frequency Error	9A
RMS Surface Micro-roughness	5A
Coatings	B_4C/Ir

G Slit Optical Characteristics

Type: Photo-etched Si Wafer	
Size	20 x 10 mm
Thickness	75 µm
Coating	Al-MgF
Length	6.2 mm
	1080 arcsec
Width	3, 6, 12, 360 µm
	0.5, 1.0, 2.0, 60 arcsec

H Spectrometer Optical Characteristics

Type: Single Reflection Toroidal Variable Line Space (TVLS)	
First Order Wavelength Range	Detector 1: 457-525 A Detector 2: 566-631 A Detector 3: 743-800 A
Grating Size	25 x 30 mm (with 2 mm margin)
RMS Figure Error	100A
RMS Surface Roughness	5A
Material	Zerodur
Aspect Ratio	6:1
Groove Efficiency	>30 %
Blaze Wavelength	600 A
Coating	B_4C/Ir
Radii of Curvature	Sag: 377.035 mm Tan: 375.000 mm
Magnification	5.67
Avg Central Ruling Density	3400 l/mm
Variable Line Space Coefficients	b2: 0.052859 b3: 0.040301 b4: 0.339541
Incident Angle α	1.105°
Diffracted Angle β	8.536, 10.660, 14.1111°
Avg Spectral Dispersion	1.9 mA/µm
Avg Spatial Plate Scale	32 µm/arcsec
Typical RMS Spot Width	8 µm
	0.25 arcsec
	15 mA

I NEXUS Detector Characteristics - Proven flight design based on CDS and SERTS

Detector	Nominal Characteristic
Type	Intensified CCD
System characteristics	Solar blind, gain: 10 CCD photoelectrons/EUV photon. full well: -15K EUV photons, readout noise: <10 electrons
Intensifier characteristics	6 micron pore microchannel plate intensifier, active area 34.8 mm square. KBr photo cathode, P43 output phosphor onto a fiber optic block
Projected pixel size	Projected CCD pixel size at instrument face plane: 17 micron or 0.53 arcsec
Coupling characteristics	Tapered fiber optic coupling from a 17 micron pixel to a 13.5 micron CCD pixels
CCD characteristics	E2V 42-40 with anti blooming. 2048x2048 format with 13.5 micron pixels
CCD orientation	Serial register parallel to the dispersion direction Both ports at 2 MHz each, nominally 1s. full frame readout

J Scanning Mirror Performance

Parameter	NEXUS Requirement	UIT Performance
Gimbal configuration	2 axis, XY	2 axis, XY
Range	±1200 arcsec	± 600 arcsec
Stability (10 min)	0.25 arcsec	<0.2 arcsec
Band width, small step	10 Hz	18 Hz
Control loop quantization	0.05 arcsec	<0.05 arcsec

E MISSION IMPLEMENTATION

E.1 Overview

NEXUS will be launched into a circular 600 km, 97.79°, Sun synchronous, 6:00 AM orbit via the Pegasus XL launch vehicle in August 2007. This orbit minimizes eclipse durations while avoiding the higher radiation dosage of higher orbits. The Mission is designed for a 2-year life. Mission operations will be controlled by four communications contacts per day used to uplink observing time lines and S/C commands and downlink stored science and observatory data. The ground station, located at RAL, provides an S-band at 128 kbps downlink and 2 kbps uplink, and an 8 Mbps X-band downlink. Table 7 summarizes this information.

E.2 System Engineering

System engineering will be managed through the development and implementation of a Systems Engineering Management Plan (SEMP) for the Mission. The SEMP will define the NEXUS Mission systems engineering tasks, activities, and products, the organizational responsibilities, and the technical resources and schedule through the mission life-cycle. While the SEMP will be used as a planning document, it will also be used as a tool to ensure that the systems engineering activities conducted by each of the partner organizations is coordinated across each work element, and is consistent with the needs of the mission.

Table 7: NEXUS Mission Information

Parameter	Requirement
Launch Date	August 2007 (Non-critical)
Launch Vehicle	SELVS II (Pegasus) with HAPS
Mission Duration	2 Years
Altitude	600 ± 15 km. [1]
Inclination	97.79 ± 0.08° [1]
Period	96.7 minutes
Eclipse Duration	21 minutes
Semi-Major Axis	6978 ± 15km [1]
Eccentricity	0 ± 0.00215 [1]
LTAN	06:00 ± 15 minutes
Ground Station	RAL
Latitude	51.5 deg
Longitude	-1.3 deg
Tx EIRP	>35 dBw with 3.7m dish
Rx G/T	>18 dB/°K (S-band) with 3.7m dish >27 dB/°K (X-band) with 3.7m dish
Modulation	S-band UL: BPSK@ 2 kbps S-band DL: BPSK @128 kbps X-band DL: 0QPSK @ 8 Mbps
Minimum Elevation	5 degrees
Contacts per Day	4 contacts baselined w/ 6 opportunities available
Contact Time	10 minutes on average
SOC interfaces	T-1 to NASA GSFC

[1] The uncertainties are based on LV capability.

Our approach to systems engineering has begun with a thorough understanding of the mission objectives. The science objectives and AO requirements were used to develop a detailed measurement concept. Once established, the measurement concept and instrument concept were validated to ensure that the science objectives will be met. In addition, an operations concept was developed to ensure that launch, deployment, and science operations will achieve the required measurement set. Throughout the formulation and implementation phases, the mission architecture and operations concept will be cross-validated to ensure consistency in meeting mission needs. This includes performing a detailed allocation of functional and performance requirements to guide the design and development of the instrument, S/C, and ground system. These requirements will form the validated basis for verification of the system functional performance.

Interface requirements and control will be documented to ensure a clean integration of the instruments and S/C into a working observatory. Interface control documents will be developed among all critical hardware elements, including S/C to instrument, to ensure hardware and software compatibility prior to integration. The mission environments, both external and internal, will be characterized to ensure that adequate margins are developed for radiation effects, electrical system grounding and noise, EMI/EMC control, and launch environments.

E.2.a Technical Resources and Margins

During development critical technical resources will be tracked. Mass, power, alignment and pointing, data volume and communications link margins, are the primary resources. Technical resource margins will be updated as detailed analyses and measured performances are obtained. The mass and power breakdown for the observatory are shown in Table 8.

Table 8: Significant power and mass margins exist for the NEXUS Mission.

Subsystem	Mass kg.	OAP W
Spacecraft Bus		
Structure	36.0	0.0
Attitude Control	15.5	41.3
Electrical Power	30.6	18.0
Command & Data Handling	7.2	23.8
Thermal	1.5	11.0
Telecommunications	10.0	12.0
Cabling	10.3	0.0
Total Spacecraft Bus	111.1	106.1
S/C Contingency	14.7	10.6
Maximum Spacecraft Bus	125.8	116.7
Instrument		
Structure/Thermal	13.9	10.0
Mechanisms/Optics	9.1	
Main Electronics	12.1	40.9
Detector Assembly	19.2	28.1
Total Instrument	54.3	79.0
Instrument Contingency	10.9	15.8
Maximum Instrument	65.2	94.8
Total Observatory	191.0	211.5
Launch / Power System Capability	230	250.6
Observatory Margin	39.0	39.1
Observatory Margin (%)	20.4	18.5
Total Margin Plus Contingency (%)	39.1	35.4

E.2.b Engineering Trade Studies

Engineering trade studies will be defined to ensure that the optimal, cost effective design is developed to meet mission needs. Currently identified trades include the potential elimination of the HAPS, the optimization of instrument mounting, use of X-band versus S-band communications, and increased reliability by selectively adding redundancy (e.g., reaction wheel, Star Tracker, Inertial Measurement Unit). These trades will be performed during the Phase A formulation activity to reduce risk, reduce cost, and optimize performance.

E.3 Spacecraft

The NEXUS S/C, shown in Foldout 4A, is based on the electronics architecture of Spectrum Astro's SA-200B core bus, as defined in GSFC's RSDO Rapid II catalog, combined with a new structural configuration. Full compliance, with margin, against the NEXUS Mission requirements delineated in Foldout 4E is achieved through minor modifications and enhancements to the SA-200B core bus. The SA-200B core bus has flight heritage, originating with the MightySat II.1 S/C launched in 2000, and the currently on-orbit RHESSI Observatory. Many of the components have also been used on Spectrum Astro's Coriolis, Swift, and Communication/Navigation Outage Forecasting System (C/NOFS) S/C. This strong flight heritage of established product designs, coupled with the minimal modifications necessary for the NEXUS Mission, will significantly reduce the cost, development time, and, therefore, risk for the NEXUS program. The NEXUS observatory system block diagram is show in Foldout 4C. The single string approach of the SA-200B provides a reliability exceeding 86% for the two-year NEXUS Mission, while exceeding mission requirements. The stowed NEXUS Observatory, shown in Foldout 4A, is easily accommodated within the Pegasus XL 44-inch envelope, with radial clearances of > 2.5 cm to the Pegasus dynamic fairing envelope.

E.3.a Instrument Accommodation

The S/C design easily satisfies the instrument requirements for quality science observations. The SA-200B bus with structural modifications, minor Attitude Control System (ACS), Command and Data Handling (C&DH), and communications component enhancements exceed all NEXUS technical specifications. A comparison of the NEXUS requirements to the capabilities of the NEXUS enhanced SA-200B bus is shown in Foldout 4E.

The SA-200B structural modifications include adaptation to the 38-inch Pegasus XL payload adapter ring and development of an octagonal configuration. The Spectrum Astro supplied instrument plate, with tripod and truss structure for instrument mounting, provides tight instrument-to-S/C alignment (±0.5 arcmin) and stability, excellent unobstructed FOV, easy access to electrical and mechanical interfaces, and solid support during launch. To maximize stability of the instrument to S/C structural interface, quasi-kinematic mounts, located on the lower half of the instrument optical bench, subtend the optical bench Center of Gravity (CG). However, the plane of these mounts is perpendicular to the instrument plate and therefore requires additional structure to couple the instrument to the S/C. The structure chosen includes structural brackets, coupled together for lateral stability, for the lower mount points and a tripod to locate the upper mount point. Quasi-kinematic blade flexures de-couple the interface structure from the instrument optical bench and are located at 120° around a bolt circle of 216 mm radius.

All bus components are mounted well away from the instrument aperture and radiator FOVs. The solar arrays (SAs) are placed well below the instrument aperture FOV and behind the radiator FOV to prevent impingement and to minimize potential contamination of the optics. The proposed structural approach allows parallel integration of the instrument to the mounting plate and S/C electronics to the bus structure. Instrument to S/C integration is accomplished by simply bolting the two structures together and mating four electrical connectors (Power, Signal, and two MIL-STD-1553). ACS enhancements include upgrade to a more precise Star Tracker Assembly (STA) to meet the mission knowledge requirements; larger Magnetic Torque Rods (MTRs) for momentum unloading; and accommodation of instrument boresight sensor data, transferred over the MIL-STD-I553 data bus, in the ACS pointing and control algorithms for augmenting control and pointing. C&DH enhancements include an upgrade to a Temperature Compensated Crystal Oscillator (TCXO) for more precise timing, and replacement of instrument interface RS-422 Driver/Receiver Chip Sets with LVDS Driver/Receiver Chip Sets (LVDS physical layer only) for compatibility with the instrument commercially procured memory. Communications enhancement includes the addition of an Offset Quadrature Phase Shift Keying (OQPSK) X-band transmitter, used on GLAST, and matching antenna. This equipment has been added to accommodate the peak science data downlink (DL) rate of 8 Mbps. Science operations during the South Atlantic Anomaly and solar eclipse season are not required.

E.3.b Mechanical Systems

The proposed S/C bus (Foldout 4A) is an eight-sided structure including struts for holding the three kinematic mounts of the instrument optical bench. Since the instrument is always Sun pointed, body-fixed arrays are used, eliminating the SA gimbals and yokes. The structure is an inexpensive all-aluminum fabrication consisting of a series of aluminum facesheet/honeycomb core panels and stringers that transfer loads to the launch vehicle adapter ring. The instrument mounting panel (or payload deck) closes out the top of the structure. The S/C components are mounted within several compartments between the top and bottom panels. The three kinematic mounts of the optical bench, similar to those used on MightySat, Coriolis and Swift, are centered about the optical bench's CG and attached to the S/C structure via a truss and tripod structure. The adapter ring on the bottom of the structure is designed to bolt directly to the standard Pegasus XL-provided 38-inch separation system.

Solar array wings are mounted on two sides of the bus structure. Each wing consists of cells mounted on two 81cm long by 43cm wide panels. When stowed, the two arrays attach to the S/C structure. Array deployment is a simple one-step sequence. The solar panel tie downs and non-explosive deployment mechanisms are nearly identical to those used on RHESSI, Coriolis, and Swift.

The solar wings, when deployed, are placed well away from and below the instrument optics and radiator such that the Observatory configuration provides greater than a 2π sr unobstructed FOV and contamination to the optics is minimized. The star tracker has been placed at the base of the S/C bus with its FOV opposite that of the instrument boresight for maximum pointing accuracy.

The launch vehicle (LV) interfaces have been reviewed and are compatible with the Pegasus XL envelope including HAPS. Environmental loads compatibility with the Pegasus XL is also ensured since the proposed NEXUS components and subsystems are derived from the Miniature Sensor Technology Integration (MSTI) 1-3, RHESSI, and C/NOFS programs, all certified for Pegasus XL LV environments. Experience on RHESSI indicates that the drop transient environment experienced when the LV is released from its L1011 carrier aircraft will require close attention. During Phase A, an analysis will be performed to ensure the tripod and truss structures provide sufficient margin for this event.

The target orbit and LV environments have been reviewed to ensure S/C compatibility. Initial examinations were also made of Observatory mass properties (mass, CG, Moments of Inertia) and fairing clearances. The Observatory mass of 191.0 kg yields a 39.0 kg margin (20.4% growth capability) against the Pegasus XL lift capability of 230 kg into a 600 x 600 km altitude orbit inclined at 97.79° from the Western Test Range (WTR). The total reserve (contingency plus margin) is 64.6 kg (39.1% growth capability).

The NEXUS Observatory stowed CG is <50.8 cm (20 inches) above the 38-inch Payload Attach Fitting, which is 20.2 cm (~8 inches) below the required CG for the 230 kg Pegasus XL lift capability.

E.3.c Attitude Control

The proposed ACS configuration, shown in Foldout 4C, is a three-axis stabilized inertial pointing system capable of meeting the NEXUS control and jitter requirements with margin (Table 9).

The ACS subsystem is comprised of four Coarse Sun Sensors (CSSs) from Adcole; one star tracker from Ball Aerospace; one Inertial Measurement Unit (IMU) from Northrop-Grumman (formerly Litton); and three reaction wheels, one Three-Axis Magnetometer (TAM), and three MTRs, all from BF Goodrich (formerly Ithaco). Modifications to the SA-200B core catalog bus, as summarized in Foldout 4B, include upgrade to the Ball CT-633 star tracker (used on SA-200S) for maintaining pointing control within ±20 arcsec and roll axis within ±50 arcsec arcmin; replacement of the obsolete magnetometer with the BF Goodrich IM-103 (used on SA-200S); increase in Torquerod™ size to 30A-m^2 (same as C/NOFS) for proper momentum dumping; and deletion of the solar array drive assemblies (SADAs).

The NEXUS requirement for continuous Sun pointing of the instrument to within ±20 arcsec, with the roll axis stable within ±50 arcsec, can be met by mounting the Ball CT-633 star tracker such that its FOV is opposite the instrument's, and mounting the three Goodrich TW-4A12 reaction wheels orthogonal to each other. Enhancement of the cross axis pointing capability to ± 0.1 arcsec is achieved by using the instrument boresight pointing data, received via the MIL-STD-1553 data bus, in the ACS control and pointing algorithms.

The star tracker assembly provides three-axis attitude knowledge to 6 arcsec on each cross axis and 30 arcsec about the roll axis. The instrument pointing knowledge of 0.1 arcsec when pointed to within 1 arcmin of the Sun will be used to further enhance the pointing control. Four CSSs provide 2π sr Sun angle measurements with ±2° accuracy for initial Sun acquisition and pointing until the S/C is pointed within the FOV of the star tracker. The LN-200S IMU provides S/C body rates and allows for attitude propagation between star tracker updates and during the Moon occultation. Canting the star tracker assembly and performing a one-time 180° roll for the eclipse season will avoid Earth obscuration.

The jitter requirement of less than 5 arcsec RMS can be met by limiting the reaction wheel speed range to avoid resonance and, if required, isolating the wheels from the S/C

Table 9: The ACS exceeds all the Mission objectives with margin.

Parameter	Requirements	Capability	Margin
Control	3-axis stabilized	3-axis stabilized, zero momentum	N/A
Reference	Inertia Sun pointing	Inertia Sun pointing	N/A
Pointing Stability & Control	± 20 arcsec in pitch and yaw ± 50 arcsec in roll	± 10 arcsec in pitch and yaw (STA) ± 40 arcsec in roll (STA)	100% in pitch and yaw 25% in roll
Knowledge	± 15 arcsec in pitch and yaw, and ± 40 arcsec in roll	± 6 arcsec in pitch and yaw, and ± 30 arcsec in roll with tracker ± 0.1 arcsec in pitch and yaw with Instrument data	150% in pitch and yaw with STA, and >1,000% with instrument data. 33% in roll with STA
Knowledge Processing	On board	On board	N/A
Deployable	Solar Arrays	Solar Arrays	Complies
Articulation	None	N/A	N/A
Scan Rate	None	N/A	N/A
Jitter	± 5 arcsec RMS	-4.4 arcsec RMS	~13%
Maneuvers	Sun acquisition and roll capability	180° rotation in <12 min about any axis	Complies
On-Orbit Calibration	Boresight to ACS	On-orbit characterization of gyro bias and STA to instrument boresight alignment	Complies

structure. During Phase A, a Finite Element Model of the S/C will be created and assessed to determine the necessity of isolating the wheels. The dual-wing fixed array on NEXUS is conservatively three times stiffer than the MightySat configuration used as the basis for the analysis. Preliminary analysis suggests the maximum jitter should be <4.4 arcsec.

The three reaction wheels, capable of storing a minimum of 4 N-m-s of momentum and generating 12 mN-m of torque in any direction, provide LV separation tip-off rate damping, attitude control, momentum storage, and slewing capability. Due to the annual variation of beta angle, the Gravity Gradient (GG) torques dominate over the solar pressure and aerodynamic torques, even at End-of-Life (EOL) low altitude. The maximum GG torque is about 0.05 mN-m, making S/C attitude recovery from any orientation easy.

The three TR30CFR MTRs, in conjunction with the TAM, are used for momentum unloading and Earth magnetic field sensing. The MTRs can unload a minimum of 3 N-m-s of momentum buildup per orbit at the NEXUS orbit inclination, providing significant margin against the worst-case GG momentum buildup (~0.29 N-m-s per orbit) and the worst case 1 deg/sec LV tip off (<0.6 N-m-s).

Acquiring and maintaining Sun pointing is the Observatory's safe configuration. The 2π sr Sun sensors oriented on the +X axis, along with the reaction wheels and MTRs, perform the following series of slews to capture and maintain Sun pointing:

- If the Sun is not present, perform a -210 degree pitch maneuver.
- If the Sun is not found, perform +210 degree yaw maneuver.
- If the Sun is still not found, return to the original inertially fixed attitude and set a telemetry bit to indicate "Sun not found," and start the eclipse timer.
- When the eclipse timer elapses, return to step 1.

The ACS algorithm design, analysis, simulation, test and flight code generation are accomplished using the Matlab-Simulink™ tool set from Mathworks.

E.3.d Electrical Systems

The solar inertial pointing nature of the mission eliminates the need for gimbaled arrays. The four-panel (two-wing), fixed, triple-junction GaAs SAs are sized to provide 250.6W Orbit Average Power (OAP) at EOL. The bus and instrument loads require 211.5W OAP including 20% instrument contingency of 11.2W and 10% S/C bus contingency of 10.6W. Given the above, the Observatory has a total of 39.1W (18.5%) margin, and 65.5W (35.4%) contingency plus margin under worst-case orbit average conditions at EOL.

Three 4A-Hr Nickel-Cadmium (NiCd) batteries provide power during ascent, separation, initialization, and eclipse, or whenever the S/C loads exceed the SA output. These batteries are rechargeable and consist of 22 electrochemical cells. Battery heaters are thermostatically controlled and the Charge Control Unit (CCU) provides automatic battery charging. The batteries are sized to limit Depth-Of-Discharge (DOD) to less than 20% under worst-case conditions. The 1,500 charging cycles and worst case DOD over the two-year mission lifetime are well within the capabilities of NiCd technology (26,700 cycles at 20% DOD).

The battery-clamped output of the CCU provides an unregulated 28±6VDC to the Observatory components. Switching in the Power Distribution Unit (PDU), housed in the Integrated Electronics Module (IEM), provides for multiple power buses, each with commandable control and sequential load shedding during anomaly situations. The Observatory power budget is presented in Table 8.

E.3.e Command and Data Handling

The C&DH subsystem (Foldout 4C) is the heart of the bus avionics system. The C&DH utilizes a RAD-6000 processor, which executes the flight software and contains specialty interfaces for all avionics subsystems. It can provide autonomous S/C bus operation for periods of up to seven days without ground intervention in normal mode, and for indefinite time periods in safe mode. Additionally, a significant portion (84 Mbytes) of the processor board's 128-Mbyte Dynamic Random Access Memory (DRAM) stores housekeeping data for ready access in anomaly situations. The processor board DRAM is also available to hold up to 128 S/C/Instrument commands. The hardware and software are compatible with Consultative Committee for Space Data Systems (CCSDS) protocols for commanding and data transmission.

Modifications to the SA-200B core bus include deletion of the SA Drive and Solid State Memory (SSM) electronics boards; modification of the RS-422 interface to meet the LVDS physical layer interface; and replacement of the standard crystal oscillator with a TCXO to meet the clock accuracy of ±0.5sec.

The IEM houses all the C&DH cards, the Integrated Power Converter Unit (IPCU), which supplies ±15V and +5V power to all S/C bus components requiring these voltages, and the PDU. The IEM incorporates an industry standard Versa Module Eurocard (VME) backplane with redundant bus, high-speed sub-bus, and is capable of accepting 6U VME form factor cards.

The PACI board includes interfaces to instruments and attitude sensors and actuators. For ACS components, it provides drivers for the reaction wheels and interfaces for the IMUs, TAM, star tracker, and CSSs. The instrument command and telemetry interface is supported with a MIL-STD-1553B data bus. Science data is read during a contact from the instrument's 7.5 Gbyte memory via the S/C provided 5 to 10 MHz LVDS clock and enable. A LVDS receiver accepts the serial science data, which is then forwarded via a VME sub-bus to the Uplink/Downlink (UDL) board for transmission.

The UDL board processes all signals to and from the transmitters/receivers. In addition, the instrument data received via the PACI across the VME sub-bus is packetized and formatted before transmission. The VME sub-bus can accommodate a data transfer rate of approximately 64 Mbps per second, easily satisfying the 10 Mbps requirement.

E.3.f RF Communications

The telecommunications subsystem design (Foldout 4C) proposed for NEXUS is the SA-200B core catalog configuration with the addition of an X-band transmitter. The single L3 Communications CXS-610 S-band Space Tracking and Data Network (STDN) transponder is used for commanding at 2 kbps and for State-of-Health (SOH) telemetry downlink at 128 kbps. It also provides range and range-rate data via coherent ranging. A filter provides additional transmit/receive isolation, rejection of spurious emissions, and immunity from out-of-band interference. The combination of two hemispherical pattern antennas on opposing S/C faces through a coupler provides effective coverage over more than 90% of the full 4π sr sphere. Separate pairs of antennas are used for transmit and receive signals. Link margin for the 128 kbps downlink at 600 km altitude with a 5° ground station elevation angle and a 3.7-meter receive antenna (18 dB/K G/T) is 12 dB greater than the minimum required to close the link with a Bit Error Rate (BER) of 10^{-6}.

The T-712 X-band transmitter by CMC Electronics, used on GLAST, transmits science data at 5 Mbps with convolution encoding, and up to 10 Mbps without convolution encoding. (Due to limited bandwidth allocation of 10 MHz, the data rate cannot exceed 10 Mbps using OQPSK modulation.) Link margin for the 10 Mbps un-encoded downlink at 600 km altitude, with a 5° ground station elevation angle and a 3.7-meter receive antenna (27dB/K G/T), is 3.5 dB greater than the minimum required to close the link with a BER of 10^{-6}. The RAL 11 meter antenna with a G/T of 32 dB/k is also available, increasing the link margin to 9 dB. The link margin for the 5 Mbps encoded data is 6 dB greater than the 10 Mbps un-encoded data due to coding gain.

The NEXUS S/C and instrument SOH is transmitted via the 128 kbps S-band STDN compatible downlink, while the science data is transmitted via the 5 to 10 Mbps X-band transmitter. Downlink characteristics are shown in Table 10.

Table 10: The STDN compatible and X-band telemetry downlink meet all Mission requirements with margin.

Parameter	Characteristic
Onboard storage	15 Gb per day of science data 128-Mbytes of RAD6000
BER	10^{-6}
Data volume	15 Gb science data, resident in instrument, and 84 Mbytes for SOH data in RAD6000 (>29 hours of SOH data)
Tx frequency	STDN: frequency pending licensing
EIRP	-0.5 dBw at S-band 8.8 dBw at X-band
Antenna & gain	> -7.5 dBi (90°) RHC cross dipole for S-band, and > 4.0 dBi (65°) RHC cross dipole for X-band
Data rate	128 kbps S-band SOH data, and 5 to 10 Mbps X-band science data
Tx power (EPS)	38 watts for S-band, and 80 watts for X-band
Modulation	BPSK for S-band, and OQPSK for X-band
Encoding	CCSDS version 1.0 for S-band, and CCSDS version 1.0 with selectable convolution encoding for X-band
Contacts/day	4 to 6, 10 minute, contacts per day
Data Destination	NASA GSFC MOC (S/C and science)
Time lag	None specified; goal is <36 hours
Licensing	Request within one month of Phase B start

The NEXUS 2 kbps commands are transmitted via an S-band STDN compatible UL with the characteristics shown in Table 11.

E.3.g Thermal Control

Elements of the NEXUS Thermal Control Subsystem (TCS) design are shown in Foldout 4C. The design uses a semi-passive control, cold-biased approach with tailored selection of surface coatings and Multi-layer Insulation (MLI) to avoid excessive solar heating while minimizing heater power. S/C and instrument temperatures are monitored using solid-state temperature sensors. Heaters are controlled via thermostats. Thermal control methodology for NEXUS is identical to the SA-200B core catalog bus and other S/C that Spectrum Astro has produced. The challenging -40°C instrument CCD temperature is achieved using a large radiator surface as depicted in Foldout 4A, and described in Section D.5.a.6, Instrument Thermal Control.

E.3.h Flight Software

Flight software, written in C++ and using VxWorks™ real-time operating system, is configured to maximize the reuse of existing code. It is estimated that approximately 60-70% of NEXUS software requirements can be fulfilled from existing code. The attitude control algorithms are auto-coded using the Real-Time Workshop™ toolset from Mathworks reducing development schedule and cost, a process with which Spectrum Astro has over 12 years of experience (Swift and C/NOFS are using the same software tools. MightySat II.1, RHESSI and Coriolis used MatrixX/Realsim™ from WindRiver, which was acquired by Mathworks). The C&DH subsystem is reprogrammable, enabling new code to be uploaded during the mission to optimize on-orbit performance for mission science return.

Table 11: The STDN compatible uplink design meets NEXUS requirements.

Parameter	Characteristic
Uplinks per day	1 for instrument modes and S/C schedule
Uplink data rate	2 kbps
Rx frequency	STDN: Frequency pending licensing
Antenna type/gain	> -7.5 dBi (at 90°) RHC cross dipole
Signal strength	> -110 dBm at antenna for 10^{-6} BER
Modulation	BPSK with no encoding
Licensing	Request within one month of Phase B start

E.3.i Manufacturing, Assembly, Integration and Test, Verification

Manufacturing and I&T of the NEXUS Observatory will begin as a distributed effort. Each team institution will be responsible for hardware production and I&T of respective assemblies in their facilities (i.e., Spectrum Astro for the S/C bus and GSFC for the instrument). These activities will be in accordance with program-level-defined requirements, schedule, and costs as outlined in this proposal. Approximately 9 months prior to launch, I&T will transition to an integrated co-located team at Spectrum Astro's facilities in Gilbert, Arizona. The flow of the NEXUS S/C and observatory I&T process is presented in Figure 7. The schedule for Observatory development and I&T through launch is discussed in Section F, Management and Schedule.

The S/C will be manufactured and tested at Spectrum Astro's Gilbert facilities using processes and procedures validated on other S/C bus and component programs (i.e., MSTI 1,2,3, Lunar Prospector, Deep Space 1, MightySat, RHESSI, Coriolis, Swift, C/NOFS and others). Instrument interface simulators will be used for early compatibility testing for risk mitigation. Component and payload interfaces will be kept simple by using open-architecture industry interface standards (e.g., MIL-STD-1553 and LVDS). This reduces risk, cost, and schedule by eliminating developmental activities, while leveraging on heritage flight programs that have been successfully executed using this same approach.

Spectrum Astro's I&T program includes the use of a S/C Hot Bench. The Hot Bench is a Spectrum Astro unique tool made up of EMs and simulators capable of simulating the completed S/C. Every component is extensively tested as a stand-alone unit, or integrated with other components in the Hot Bench. Early unit tests ensure validation of interface, signal, and timing requirements. This approach of thorough and repeated test at all hierarchical (component and system) levels has proven effective in identifying and resolving issues early, avoiding the higher costs of resolving them later in the program. To reduce Observatory I&T risk GSFC will make available instrument EM hardware to validate signal and functional (e.g., boresight data) interfaces with the Hot Bench.

After the S/C bus has completed system level testing at Spectrum Astro, it will be readied for

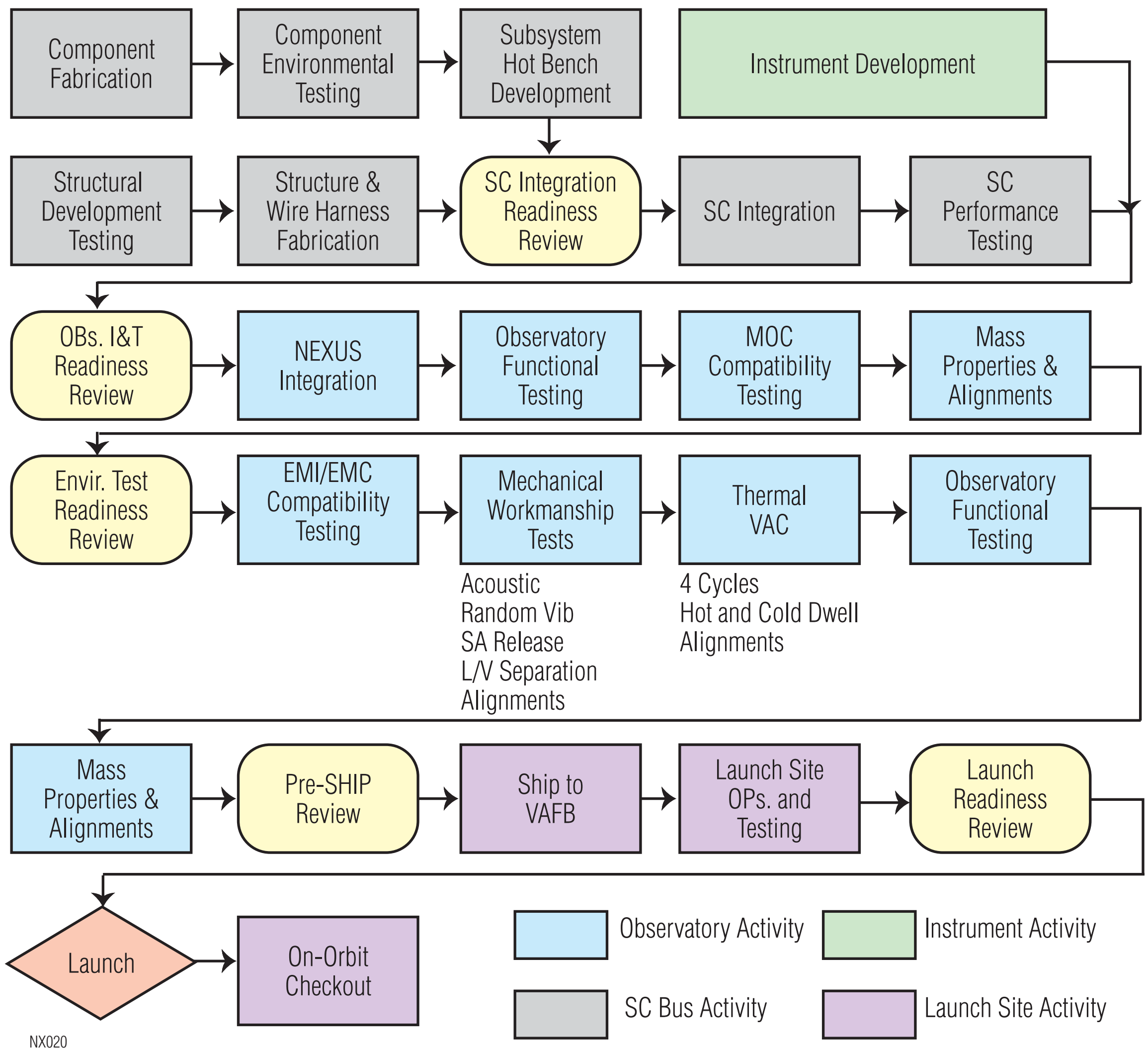


Figure 7: NEXUS Integration and Test Flow is based on previous successful programs.

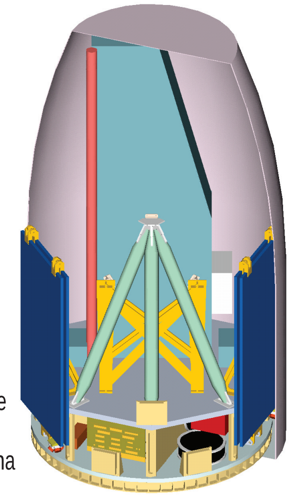
Observatory-level integration and environmental testing. Compatibility of the S/C with the GSFC MOC, RAL and Launch and Early Orbit (L&EO) ground stations is verified during Observatory I&T, including a day in the life simulation. The environmental testing consists of EMI/EMC, mechanical workmanship (acoustic, random vibration, and shock), and thermal vacuum/balance. EMI/EMC testing will use MIL-STD-461E RE-102 and RS-103 as guidelines and will be modified as required to demonstrate observatory self, launch vehicle, and range compatibility. For acoustic and random vibration tests, the Observatory will be configured for launch, including the SELVS separation mechanism, and exposed to proto-flight levels (3 dB above maximum expected flight). For shock, the SELVS separation and SA release mechanisms will be exercised to demonstrate their operation and to expose the Observatory to the expected shock environment when these devices are initiated. Thermal vacuum testing will consist of four thermal cycles, and one hot and cold thermal balance. The temperature limits will be such that all thermostats are cycled, and sufficient data is collected for thermal model and design validation. At the conclusion of observatory environmental testing, a final comprehensive functional test of the spacecraft and instrument will be conducted to verify the observatory's readiness to ship to the launch site. At the conclusion of testing, the NEXUS S/C and instrument will each have accumulated more than 800 hours of total operating time prior to launch, with the last 200 hours of Observatory time failure free, to reduce the possibility of on-orbit failure due to "infant mortality".

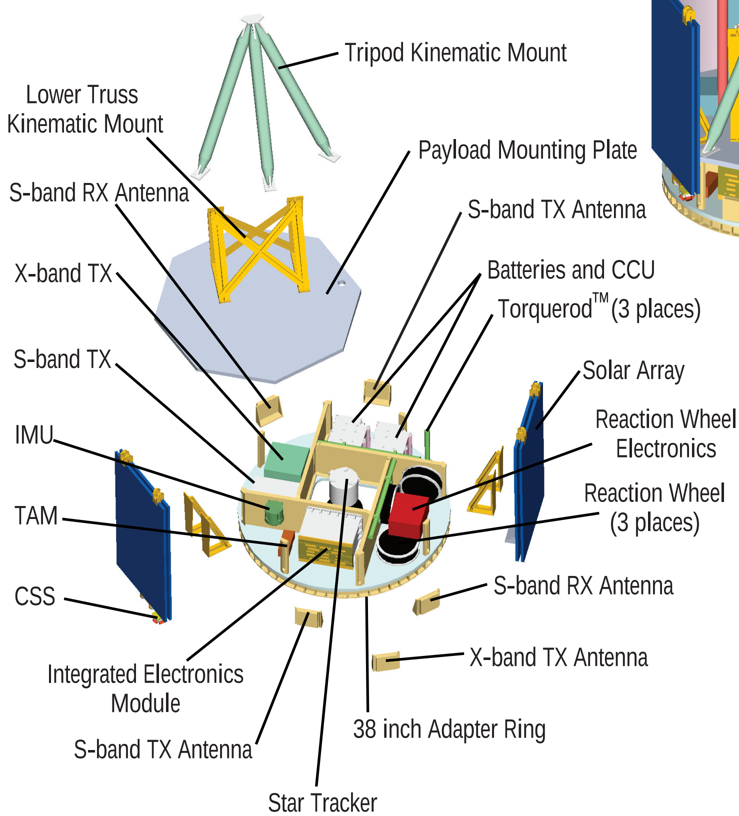
The 30-day L&EO checkout will cover post-launch system evaluation and configuration

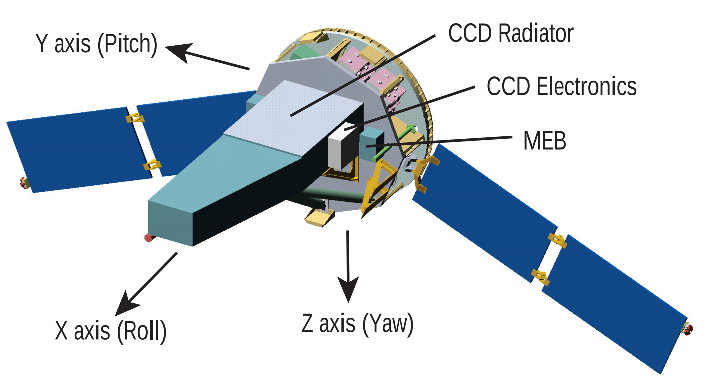
FOLDOUT 4

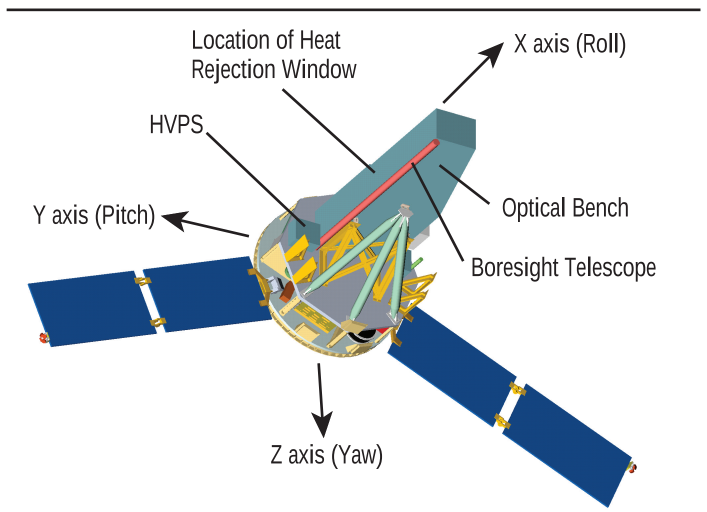
NEXUS Spacecraft

A Stowed and Deployed NEXUS Observatory Configuration





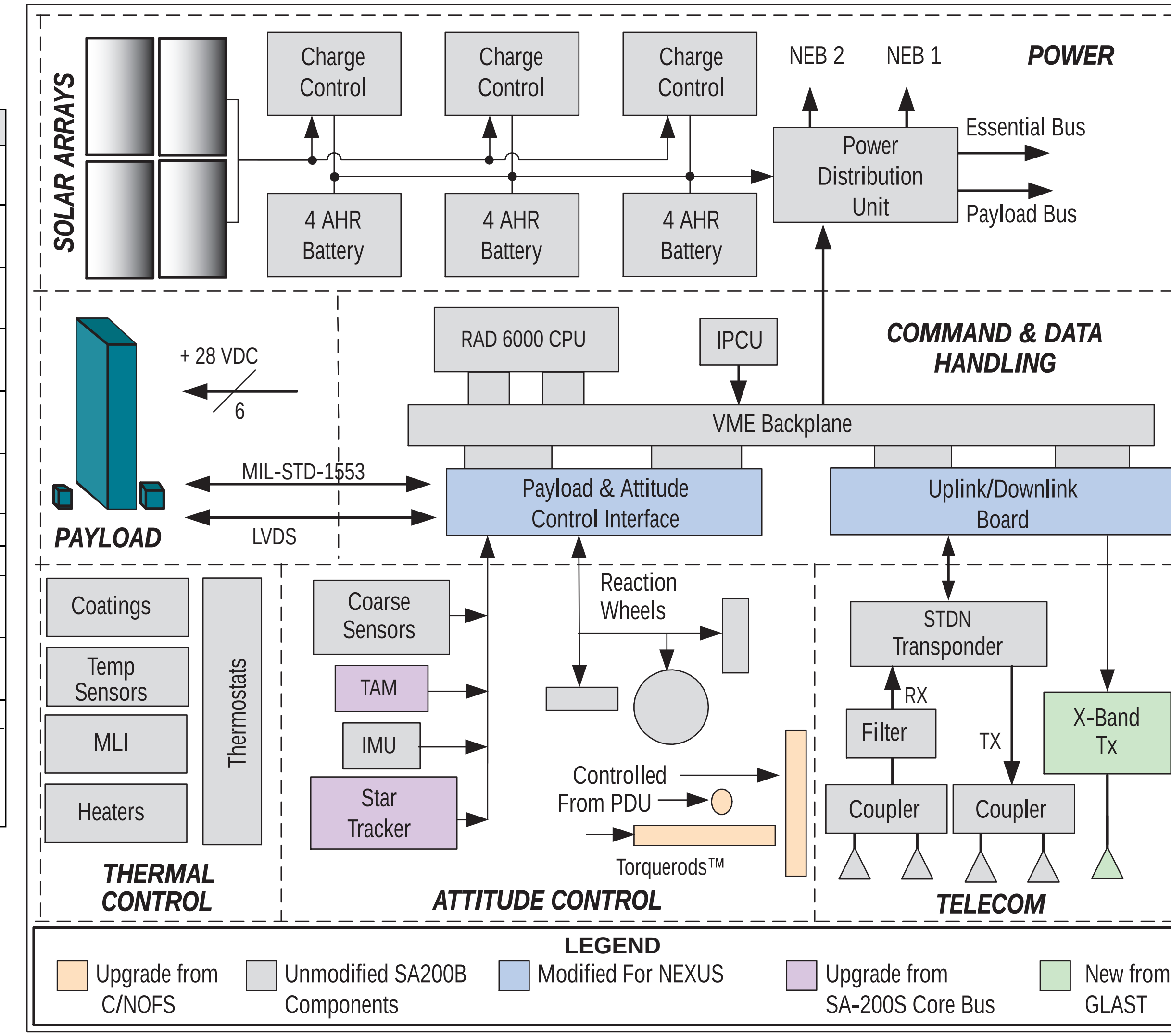




B Mission Unique Changes to the Core SA-200B Core Bus are Low Risk

Sys	Modification	Impact
Structure	Accommodation of instrument and SC components, and LV 38 inch interface	Design and fabrication techniques well known
ACS	Upgrade to CT-633 Star Tracker to meet pointing requirements	CT-633 Star Tracker used on Coriolis (On-Orbit)
	Replace Three-Axis Magnetometer for Parts Obsolescence	TAM used on Coriolis (On-Orbit)
	Upgrade to 30 Am^2 Torquerods™ for unloading gravity gradient torques	Torquerods™ used on C/NOFS
	Delete Solar Array Drive Assembly (SADA)	Removing SADA presents minimal risk
Electrical Power	Replace articulated solar array with body-fixed arrays	Fixed arrays are less risky
C&DH	Delete Array Drive Electronics (ADE)	Removing ADE presents minimal risk
	Delete Solid State Memory (SSM)	Removing SSM presents minimal risk
	Replace RS-422 with LVDS to meet instrument interface	Replace with pin compatible LVDS parts
	Upgrade to Temperature Compensated Crystal Oscillator for ±0.25 sec accuracy	High reliability flight heritage parts available with identical foot print
Telecom	Addition of X-band Transmitter	Transmitter used on GLAST
Mission Assurance	GSFC311-INST-001 Level 2 Parts Program	Most parts are Level 2, others to be up screened. IMU not Level 2, but on-orbit in Coriolis

C NEXUS Observatory SA200B Based System Block Diagram Makes Extensive Use of SA200B Core Bus



D Instrument Accommodation Requirements

The NEXUS Spacecraft accommodates all instrument requirements with margin through minor modifications and enhancements to the SA200B bus.

Parameter	Requirement	Capability
Boresight FOV	0.3 deg. Half cone	>2πsr FOV
Radiator FOV	Sufficient view of deep space to maintain <-40°C	~2πsr FOV. Refer to thermal section of instrument description for thermal design, Section D.5.a.6
Timing accuracy	±0.5 sec/day	±0.25 sec/day with TCXO upgrade
Jitter	<5 arcsec RMS	<5 arcsec with SA gimbals and yokes removal
Cleanliness	- Class 100 when interior is exposed - Class 10,000 with instrument bagged External Surface: - Level 300A Molecular: - Class 10,000 Particulate: - MIL-STD-1246C level A	-Class 100 environment achieved via local area control using instrument provided laminar flow clean bench -Class 10,000 environment satisfied with clean tent -Contamination plan to be developed similar to Swift and STEREO
Radiation	3Krad behind 100mils Al	>24 Krad at piece part level
Pointing control	±20 arcsec in pitch/yaw and ±50 arcsec in roll	±10 arcsec in pitch/yaw and ±40 arcsec in roll achieved with enhanced STA
Boresight pointing data	Use boresight pointing data for increased accuracy (±0.1 arcsec)	Easily accommodated into ACS control algorithms
Mission duration	2 years	2 years with reliability >0.86
Instr. power w/contingency	94.8 W	>18% Observatory power margin (Table 8)
Instr. weight w/contingency	65.2 kg	>20% Observatory weight margin (Table 8)
Instr. cmds/SOH	MIL-STD-1553	MIL-STD-1553
Science data interface	LVDS @ 8 Mbps (Clock, Data, and Enable)	Replace 5 Mhz RS-422 Driver/Receiver chip set with 10 Mhz LVDS for Clock, Data, and Enable
Science data storage	Instrument stores all science data	N/A
Maneuvers	Sun requisition and roll capability	180° rotation in <12 minutes about any axis

E System Level Requirements are Satisfied with Substantial Margin

Parameter	Margin	Requirement	Capability
Mass	20.4%	191.0	230.0
Power	18.5%	211.5	250.6
Battery Capacity	17.6%	10.2 Ahr	12 Ahr
Attitude Control (Cross Axis)	100.0%	±20 arc-sec	±10 arc-sec
Attitude Control (Roll)	25.0%	±50 arc-sec	±40 arc-sec
Attitude Knowledge (Cross Axis)	150.0%	±15 arc-sec	±6 arc-sec
Attitude Knowledge (Roll)	33.0%	±40 arc-sec	±30 arc-sec
Jitter (RMS)	19.0%	±5 arc-sec	±4.2 arc-sec
Instrument Science Data	25.2%	8 Mb	10 Mb
Instrument SOH Data	156.0%	2 Kb	5.12 Kb
Instrument Commanding	156.0%	1 Kb	2.56 Kb
Memory (Science Data)	-	Not required	Not required
Link Margin: U/L (Rx Signal)	13 dB	< -97 dBm	-110 dBm
Link Margin: SOH D/L (EIRP)	12 dB	> -12.5 dBw	- 0.5 dBw
Link Margin: Science D/L (EIRP)	3.5 dB	>5.3 dBw	8.8 dBw
Radiation (Total Dose)	700.0%	3K[1]	24K[1]

Notes:
1. 3K is with 100 mil Al, 24K is at part level

of S/C and Instrument. During initial acquisition following separation, the Flight Operations Team (FOT) will perform an evaluation of the health and safety of the S/C. A well-defined and rehearsed checkout of the Observatory leading to normal operations follows. Use of the RAL ground station and other STDN compatible resources will be scheduled for this period to facilitate early checkout activities and provide for rapid anomaly response if necessary. During this early period, initial communications will be established to check out command telemetry links and to verify nominal SOH of the S/C. Other L&EO milestones include power and thermal subsystem characterization. Instrument initialization and calibration will be performed after basic S/C performance is verified. The Instrument and detectors will be outgassed for approximately 20 days after launch before high voltage is enabled.

E.3.j Mission Assurance

The scope of the S/C mission assurance activities includes Quality Control, inspection, system safety, parts selection and control, materials selection and control, reliability, problem/failure reporting, and software validation. Spectrum Astro will be in full compliance with its ISO 9001 process and with the NEXUS Project mission assurance requirements. Mission assurance support activities and products for all aspects of the observatory are the responsibility of the NEXUS Project at GSFC, as described in Section E.5. Contamination control is especially critical for the instrument and will be given priority and management attention.

Spectrum Astro's contamination control procedures will be developed to meet the NEXUS contamination requirements and will be implemented throughout the entire program (S/C design, manufacturing, and I&T, and Observatory I&T) to preclude and reduce particulate and molecular contamination of the NEXUS optics and to meet 300A S/C cleanliness requirements. (Similar procedures used on Swift achieved 400A cleanliness against a 600A requirement.) The contamination control procedures include: bus assembly and I&T conducted in Class 100,000 facilities and instrument double bagging with gaseous nitrogen purging. A Class 10,000 environment is used whenever the NEXUS instrument is unbagged, and a Class 100 environment (portable tent/bench provided by GSFC) is used whenever the door or interior surfaces of the instrument are exposed. Similar precaution will be taken throughout S/C environmental tests (EMI/EMC, mechanical workmanship tests, and thermal vacuum), shipment, and LV integration and launch site activities. Class 3,000 fairing air will be specified during launch site and captive carry activities.

E.3.k Ground Support Equipment

Aside from the various standard laboratory test equipment such as oscilloscopes, spectrum analyzers, and digital volt meters, there are specialized items required to test components, units, subsystems, systems (S/C and instrument) and the Observatory. The two major pieces of test equipment are the Hot Bench, and the AstroRT command and telemetry processor.

The Hot Bench, a S/C in a rack, uses engineering model duplicates of the C&DH with simulators and/or EMs for subsystems, and peripheral hardware, such as the xPC-Target™ by MathWorks. The xPC-Target™ coupled with Simulink™ software is capable of simulating all the ACS sensors and actuators, providing the ability to perform real-time simulations using the flight processor, its interfaces, and the flight software. The use of Simulink™ and xPC-Target™ provides the ACS subsystem engineer, systems engineer and mission engineer with an excellent tool to verify pointing capabilities, performance and, in the case of NEXUS, the ability to simulate response to the boresight pointing data via the MIL-STD-1553 data bus.

AstroRT is Spectrum Astro's Real-Time Data Acquisition and Control Software Package used during unit and subsystem test, and S/C and Observatory I&T. AstroRT is based on National Instruments LabVIEW™ and Microsoft™ Visual C++ software, and was originally developed to support TDRS H, I, J backup command and telemetry at White Sands. It has been used to support numerous Spectrum Astro programs including MightySat II.1, Coriolis, and C/NOFS.

NEXUS will make extensive use of C/NOFS existing mechanical ground system equipment.

E.4 Ground Segment

The NEXUS operations concept derives heritage from the one developed by GSFC for TRACE. To keep the mission operations costs of the program low, NEXUS will adopt the streamlined approach based on two major components: Mission and Science Operations Centers (MOC, SOC) located at GSFC; and for uplink and downlink, a contributed ground station located at RAL.

Communications between GSFC and the RAL antenna will be conducted via a dedicated communications line. A T-1 grade communications line will be sufficient to handle the modest real-time commanding and telemetry requirements, as well as to send back the full-resolution science data post-pass.

Beginning with the science perspective, a weekly science planner will generate a daily schedule to accomplish the NEXUS observing goals. The planning and scheduling software tools already exist for SOHO CDS (e.g., [52]), and only minor modifications will be necessary to accommodate the enhanced capabilities of NEXUS. A variety of context data (e.g., NEXUS quick-look images, magnetograms, and NOAA SXI images) will be used to select targets, and all of these will be available to the science planner, along with existing tools to manipulate those data. The science plan will specify targets and programs to be run for at least 24 hours following the uplink.

About 90 days after launch, the FOT will pursue a “lights out” nominal operations philosophy whereby they are resident at the MOC only during local business hours. Automated workstations will monitor the real-time telemetry during contacts whether the MOC is staffed or not. Housekeeping (HK) telemetry decommutation, monitoring, and display will be automated, and Internet pages will be accessible to the FOT. Similar to TRACE, out-of-limit telemetry parameters will trigger a paging device for one-or-more FOT members who are on-call. (SOC discussed in D.5.b.)

A small amount of science data (called quick-look, or QL) will be available with the HK in near-real-time during the pass. This science data will be highly compressed, full-disk synoptic maps at select wavelengths, which will be useful for several purposes. First, the data will provide verification of the overall health & welfare of NEXUS, and it eliminates expensive data latency requirements for the entire telemetry stream. Second, the images will provide up-to-date imaging data for the science planner. Third, an appropriate selection of wavelengths (e.g., Ne VIII) will provide timely information of trans-equatorial coronal holes for space weather that will be far superior to the GOES SXI data, which image plasma that is too hot to show these geoeffectively-important features.

Since the HK and QL telemetry will have the highest priority during contact with NEXUS, the bulk of the science data will be copied from RAL to GSFC during intervals between contacts. RAL will keep a 30-day archive of the raw telemetry frames online, and no data will be erased before verification has been received that it is archived at GSFC.

NEXUS will pursue a completely open data policy. Data handling procedures will be automated to the extent possible, both to insure that data are available to the science community in a timely fashion, and to eliminate the need for data technicians. Archiving of the NEXUS telemetry, higher level science data, and ancillary mission data, will be provided by the VSO. The ancillary mission data include items such as Daily NEXUS Status Report, Daily Science Planner Report, etc.

Flight software maintenance will be provided, with support from the S/C provider if required. MOC software maintenance will be available from the GSFC developers if necessary. The data analysis software tools already exist as heritage from SOHO CDS. The NEXUS scientists will maintain all science planning and analysis software tools.

All NEXUS flight operations will be conducted from GSFC. Communication with NEXUS will be through a 3.7-meter fully-steerable S-band/X-band antenna located at RAL, with a 12-meter antenna as back-up.

The RAL ground station has significant operational heritage, as it has been used to capture the ACE Real-Time Solar Wind telemetry stream[53] as well as IRAS. RAL will also be used to capture the Space Weather Beacon telemetry from NASA's STEREO mission beginning in 2006[54].

E.5 Product Assurance

The Mission Assurance Requirements (MAR) for NEXUS will be defined in a project specific MAR implementation plan developed using the SMEX MAR and the GSFC Mission Assurance Guidelines. The quality assurance effort at GSFC will follow the GSFC Quality Management System (QMS), GPG 8730.3. The GSFC QMS is registered as compliant with ISO 9001-1994. The system is currently being updated to be compliant with the 2000 version of ISO 9001.

Safety: A safety engineer will be assigned to the NEXUS team to help plan and implement a system safety program, including the development of a System Safety Program Plan. This plan will describe the process that NEXUS will use to identify, evaluate, and eliminate or control hazards (e.g., instrument high voltage power supply) throughout all stages of the program. System safety requirements will be derived from Eastern and Western Range 127-1. NEXUS Mission system safety personnel will also perform a hazard analysis (HA) at all program phases. Hazard controls will be implemented in hardware design and applicable procedures. Throughout the evolution of the HA, the identified risk will be jointly resolved between the responsible functional elements and the Safety Engineer. Resolution of each identified hazard in the HA is accomplished by the system safety review of the associated test reports, engineering drawings, engineering analyses, procedures and task flow charts or the surveillance of tests and demonstrations.

Parts Selection: In general, all parts will be selected and processed in accordance with GSFC 311-INST-001, "Instructions for EEE Parts Selection, Screening, and Qualification" for Level 2 quality level for added reliability. A parts review program will be implemented to review all parts relative to their use in the S/C or instrument. Special attention will be given to the area of radiation effects due to the radiation environment anticipated for this mission.

Materials Assurance: A Materials and Processes program will be implemented starting in Phase B. Materials and processes for the S/C and instrument will be reviewed by the GSFC Materials branch.

Reliability: Reliability analyses will be performed for the instrument and S/C. These include a Failure Modes and Effects Analysis, Probabilistic Risk Assessment, and Fault Tree Analysis.

Software Quality Assurance: The instrument and S/C will develop software requirements specifications and interface requirements documents which include traceability to higher-level system specifications. In addition, a software development plan will be generated. The Instrument and S/C will hold internal and external reviews, where the design and architecture is shown to satisfy its requirements and interfaces. A software test plan will be developed for the Instrument and S/C listing the testing required at both build and system levels. A requirements verification matrix will be generated from the requirements document that assures that all requirements are verified and validated. All flight software will be configured and controlled by each component until delivery to I&T, after which all changes will be controlled by the Project Software Configuration Control Board (CCB). This includes any changes during on-orbit maintenance. A software problem report database will be used to track all changes by the CCB. The NEXUS team will coordinate with the NASA IV&V Facility staff, as required by current NASA program guidelines, to obtain an independent review of the software development process.

E.6 Launch Vehicle

The baseline launch vehicle is the SELVS II (Orbital Sciences Pegasus XL) with a HAPS option. The NEXUS observatory will be launched from the WTR directly into the final 600 km circular, 97.79° inclination, Sun synchronous mission orbit.

F MANAGEMENT AND SCHEDULE

F.1 Management Approach

The NEXUS project is a collaboration among GSFC, NRL, University of California, Berkeley (UCB), Spectrum Astro, and RAL. Team members were chosen because of their unique capabilities and expertise, as well as a long history of collaboration on solar physics missions (SOHO/CDS, SOHO/LASCO, STEREO/SECCHI, Solar-B/EIS, SERTS). These institutions have decades of experience in solar physics, and NEXUS can draw on unparalleled institutional resources that include every kind of technical specialty, facility, and process within the state-of-the-art. Each of these institutions has a well-defined responsibility, and has the resources and experience to accomplish their portion of the mission. The NEXUS approach emphasizes simplicity of design and clear lines of authority. The proximity of GSFC to NRL facilitates communication between the institutions with instrument hardware responsibility. Clean, simple interfaces will simplify the implementation of International Traffic in Arms Regulations (ITAR) related agreements for the RAL contribution.

The NEXUS implementation approach uses tailored system engineering for concurrent design and development; bottom-up risk management;

fabrication plans and methods (e.g., contamination, stray light analysis) based upon previously flown, successful solar physics instruments; and an appropriate performance assurance approach.

Parts selection, failure analysis and risk management will be integral to the conceptual and detailed design process. A protoflight approach will be implemented for development and qualification of the flight instrument and S/C. In order to minimize schedule and cost risk, engineering model hardware will be fabricated and functionally tested to validate the performance of critical hardware elements prior to flight hardware development.

Communication among the various NEXUS team members is essential for project success. The entire NASA-funded portion of this investigation is the responsibility of GSFC, with strong participation from NRL. The close proximity of these institutions will facilitate face-to-face interaction on a regular basis. We will conduct regular meetings of the NEXUS management team to discuss mission progress, schedules, costs, and development issues, as well as weekly staff meetings with selected team members. We will also conduct formal monthly status reviews. Team members not present at staff meetings or monthly reviews will participate by telecon. As needed, additional telecons will be arranged to address specific issues. In addition to the monthly status presentations, each U.S. team organization will submit monthly financial reports for analysis by the NEXUS Mission Business Manager (MBM). The NEXUS Project Manager (PM) will utilize the input from all team members to compile the monthly status review for senior GSFC management.

F.1.a Management Organization

We have formed a small, tightly integrated team to implement the NEXUS Mission, as shown in Figure 8. NEXUS project management will be compliant with NPG 7120.5B as tailored to meet the specific needs of a modest development effort. The management approach adopts best practices from successful GSFC, NRL, and Spectrum Astro projects to provide the structure and processes needed to meet all NEXUS requirements.

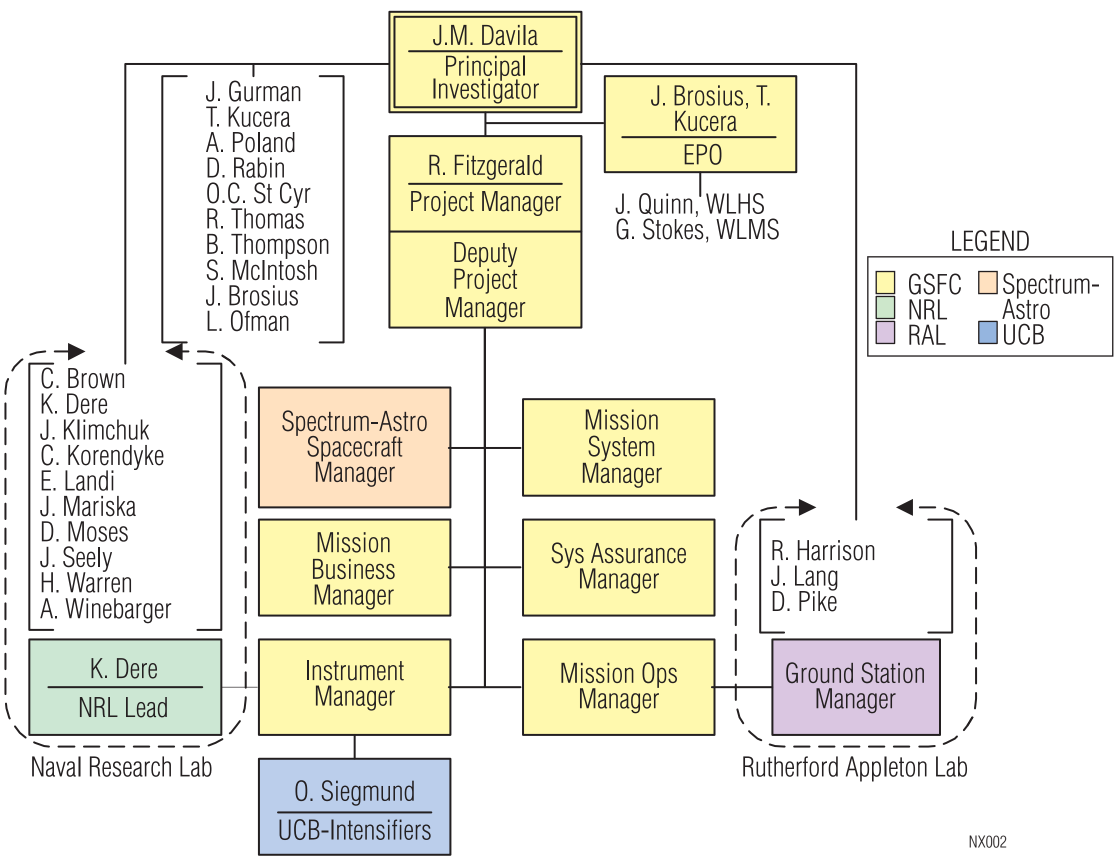


Figure 8: NEXUS Organization Chart

F.1.b Decision-making Process

NEXUS will implement a straightforward decision making process. The PI bears ultimate responsibility for all decisions, but will delegate the technical and programmatic implementation of the project to the PM. The PM will approve all mission level changes that affect technical or programmatic resources. The PI will approve all changes that affect science.

F.1.c Teaming Arrangements

The PI institution for the mission will be GSFC. RAL, NRL, and UCB will participate as Co-I institutions. Spectrum Astro was selected through a competitive RSDO process and will participate as the S/C partner. Each of these organizations will play an integral role in developing the science architecture for the mission, as well as be involved in the development of the instrument prior to launch.

F.1.d Responsibilities of Team Members

GSFC is the lead institution for NEXUS, providing overall mission project management, science and Education and Public Outreach (E/PO) leadership, system engineering, performance assurance, and resource management. GSFC also has management and system engineering responsibilities for the instrument, with portions of the electronics and mechanical system being provided by NRL, and detector assembly intensifiers provided by UCB. RAL will provide the ground station for on-orbit operations, with mission operations conducted at GSFC.

Upon selection, GSFC will finalize Statements of Work and appropriate agreements with NRL, UCB, RAL, and Spectrum Astro. All NEXUS funding will be provided to the GSFC Project Office for dissemination to the participating institutions. NRL and UCB will be funded through the use of a procurement contract. A Letter of Agreement (LOA) will be negotiated defining RAL participation, which will be on a no-exchange-of-funds basis. These agreements will be managed as formal contracts, with defined milestones and deliverables.

Spectrum Astro has been awarded a “contingent delivery order under RSDO contract NASS-00110.” Upon selection for Phase A study, Spectrum Astro will be issued a delivery order for $250K, with an option to proceed for the S/C.

F.1.e Team Member Unique Capabilities and Relevant Experience

All of the key NEXUS team members are recognized experts in their respective fields and are fully committed to the success of the NEXUS Mission.

The hardware institutions all have extensive experience building successful space instrumentation and delivering it in a timely fashion. In particular, GSFC has built space flight instrumentation since its inception in 1959, and is respected internationally for its accomplishments in space sciences. Recent GSFC mission development experience includes RHESSI, MAP, SOHO, and TRACE, among many others.

NRL has a strong background in solar physics research and development, including missions such as SOHO, Solar-B, and STEREO. Much of the electronics design for the NEXUS instrument is traceable to successful NRL developed hardware and software for these missions.

UCB has flown image intensifiers on many missions, both for spaceflight missions and for sounding rocket. They are currently participating in the STEREO mission development. UCB is the world leader in producing intensifiers for spaceflight.

RAL also has extensive experience in mission design and development. In particular, they have had ground communications facilities in operation for many years, with the ACE mission as one recent example. In addition, RAL has conducted numerous solar physics mission calibration efforts in a state-of-the-art facility located on its campus.

Spectrum Astro is a recognized leader in the development of small, efficient S/C and space instrumentation. Their recent experiences on RHESSI, Coriolis, and MightySat make them highly qualified to partner with us for this mission.

F.1.f International Contributions

RAL will be participating with us as Co-Investigators, and as ground station and instrument calibration provider for the mission, contributing unique services on a no-exchange-of-funds basis. During Phase A, we will begin the process of establishing a LOA with RAL in order to document the cooperation between the two institutions. Our experience at GSFC on SOHO and ACE has made us fully cognizant of the restrictions imposed by the ITAR. The NEXUS plan for timely establishment of ITAR agreements can be found in Appendix 5.

F.2 Roles and Responsibilities

Key managers and their responsibilities are shown in Table 12. Dr. Joseph Davila of GSFC,

Table 12: NEXUS Roles and Responsibilities

Principal Investigator (GSFC)	• Ultimate accountability for NEXUS investigation • Complete accountability for all science activities • Member of NEXUS Science Team • Point of contact for science communication with Explorers Program at GSFC • Authority for science descope decisions • Primary oversight responsibility for implementation of NEXUS Education/Public Outreach Program
Project Manager (GSFC)	• Complete accountability for implementation of NEXUS Mission • Point of contact for non-science communication with Explorers Program at GSFC • Authority for all cost and schedule decisions, including utilization of cost and schedule reserves • Authority for non-science descope decisions • POC for international partner agreement with RAL, technical and schedule status • Oversee technical, cost and schedule performance of all GSFC, NRL, and UCB activities • Prepare and present monthly status presentations to GSFC management
Deputy Project Manager (GSFC)	• Responsibility for day-to-day implementation of NEXUS project • Authority for all technical decisions, including utilization of mass and power reserves • Leads technical insight/oversight activities for NEXUS Project • Chair of NEXUS Configuration Control Board • Focal point for mission risk management activities • COTR for contractual agreement with Spectrum Astro, technical, cost, and schedule status
Mission System Manager (GSFC)	• Provide System Engineering oversight for entire NEXUS Project • Responsible for interface definition and control among NEXUS elements • Responsible for creation and maintenance of NEXUS Verification Matrix • Responsible for oversight of mission I&T programs and subsequent compliance to Verification Matrix • Chair all NEXUS technical peer reviews
Instrument Manager (GSFC)	• Complete accountability for cost, schedule and technical performance of instrument • Authority for all decisions involving cost, schedule, interfaces and technical performance issues (within instrument) which do not affect other elements of NEXUS • COTR for contractual agreements with NRL and UCB • Responsible for implementing instrument I&T program and subsequent compliance to NEXUS Verification Matrix • Responsible for creation, maintenance and statusing of milestone schedule network for instrument • Responsible to GSFC NEXUS Project for all financial, schedule and technical performance reporting, including identification of concerns and issues • Prepare and present monthly status presentations to NEXUS PI and PM
Spacecraft Manager (Spectrum Astro)	• Responsible for end-to-end design, development, test, and evaluation of the S/C bus and associated GSE • Point of contact for formal communication with NEXUS Project at GSFC • Responsible for instrument integration with S/C and subsequent observatory I&T • Leads NEXUS engineering support activities at launch site prior to launch

as the NEXUS PI, will have overall accountability for the mission. Dr. Davila will be supported by experienced management, scientific and engineering personnel working within a focused environment. Dr. Davila will delegate the programmatic and technical implementation of the project to Mr. Richard Fitzgerald, an experienced GSFC PM. Mr. Fitzgerald will manage all mission activities associated with the development of the flight and ground hardware and software. Assisting the PM will be a GSFC Deputy Project Manager (DPM), who will be responsible for day-to-day implementation of the Project and management of our S/C partner, Spectrum Astro. The GSFC Mission Systems Manager (MSM) will lead a strong systems and discipline engineering effort to thoroughly identify, track and verify requirements and to make trade decisions. The GSFC System Assurance Manager (SAM) will lead the mission assurance effort to assure a quality program. The GSFC Mission Operations Manager (MOM) will lead the overall on-orbit operations planning, including the interface with the RAL ground station and pre-launch operations simulations. The NEXUS management team, including Science, Project Management, System Engineering, Operations, and Mission Assurance will be co-located and meet regularly to resolve science, technical and programmatic issues. The MBM will coordinate the disposition of NEXUS funds, solicit monthly financial reports from each institution and report status to the PM and PI. In addition, the

MBM will also manage and coordinate all configuration management, project planning, and procurement activities for the Project.

GSFC also has lead responsibility in the management of the NEXUS instrument, including the in-house development of the optical system, primary structure, and detector assembly electronics. The Instrument Manager (IM) will be responsible for all technical and programmatic aspects of the instrument. Support from NRL will be in the following areas: design and development of the instrument MEB, mechanisms, and CCD procurement. These tasks include detailed design, fabrication, I&T, development of interfaces, configuration control, quality assurance, safety, systems and discipline engineering, mechanism characterization, and developing documentation for reviews. The NRL instrument development effort will follow an institutional and management approach successfully implemented on a variety of programs and will be directed by Dr. Kenneth Dere. Dr. Dere will supervise a team of skilled, experienced engineers, scientists, and technicians who will carry out the requisite development program. The in-house team will be supplemented with discipline engineering support from Swales Aerospace, as required. UCB will have responsibility for the design, development, test and delivery of the detector assembly image intensifiers. This effort will be directed by Dr. Oswald Siegmund.

F.3 Risk Management

The NEXUS risk management plan provides a procedure for early risk identification, tracking, and mitigation. Any NEXUS team member may identify and submit a risk. These inputs are reviewed and classified by type, severity, and probability of occurrence and then are placed on a watch list. Risks affecting system and intrasystem margins will be tracked as Technical Performance Measures (TPMs). A TPM is a physical quantity tracked to provide visibility into whether a system will actually meet requirements (e.g., mass, power, data rate, memory utilization, qualification of parts, reliability estimates, completion of crucial analyses). A Risk mitigation plan for each identified risk will be developed and acted upon to minimize impacts on system requirements, cost, and schedule. The top NEXUS risks and associated mitigation strategies are described in Table 13.

F.3.a Descope Strategy and Options

Descope options have been identified that can be implemented to reduce cost, mass or power, or to improve schedule during the mission development process (Table 14). The phasing of these options varies throughout the life-cycle of the Project in order to provide the PM with flexibility should the need arise. These options, combined with the strong technical and programmatic margins, provide for a robust mission.

Table 13: Top NEXUS risks have clear mitigation strategies identified.

Risk	Potential Impact	Mitigation
Toroidal Variable Line Space (TVLS) Grating	If grating fails to meet spectral, spatial, or efficiency requirements, then Baseline Mission cannot be accomplished	• 4 Proposals obtained • TVLS gratings to be purchased from 2 vendors • SVLS grating also purchased as a backup to meet MM requirements • Initiate procurement planning in Phase A
Ground station to be operated by foreign contributor	If foreign contribution is not realized, then there is no budget allocated for ground station ops in MO&DA	• GS development budgeted by GSFC as part of Baseline • Reevaluate in Phase A
ITAR	If requirements cannot be communicated to foreign contributors, then mission cost and schedule are adversely affected	• Single foreign institution reduces risk • History of collaboration with RAL • Begin LOAs early
Integration of instrument boresight error signal into S/C ACS	If boresight telescope does not operate properly in the ACS system, then fine pointing requirements cannot be met.	• Closed-loop testing with the Hot Bench verifies interfaces early in program • "In-the-loop" testing at the S/C level with solar simulator will validate operational mode
Hydrocarbon and particulate contamination	If the instrument or detectors are contaminated, then sensitivity will not meet requirements.	• Comprehensive contamination control plan initiated from the beginning • Instrument apertures substantially forward of potential contamination sources • Materials tracked for potential problems • Analyses of on-orbit conditions

Table 14: NEXUS descopes provide options at all mission phases to reduce cost and schedule risk, while providing a "graceful degradation" of science return.

Description	Phasing	Effect	Savings	Value
Shorten instrument	Phase A	Reduced effective area while maintaining f/number	9 kg mass reduction	Reduce instrument mass
Delete slit mechanism	PDR	Decreases FOV by factor of 2, reduced selection of observing modes	$500K, 2 kg	Reduce instrument cost, mass and risk by eliminating mechanism
Delete HAPS	PDR	Potential for reduced mission life (but not used for TRACE)	$750K	Reduce LV cost, increased reliability (Note: This option to be studied in Phase A)
Low coating or detector photocathode efficiency; choose to use backup SVLS grating	Prior to final instrument I&T	Reduced spatial resolution to maintain exposure time, still meets minum mission	Maintain development schedule	Avoid cost growth due to schedule delay
Reduced number of ground passes per day	Prior to MO&DA	Some data loss, uses all margin	$500K	Reduce MO&DA cost
Shorten mission life	Prior to MO&DA	Reduce CME sample observed from 40 to 20	$1M	Reduce MO&DA cost

F.3.b Control, Allocation, and Release of Margins and Reserve

All mass, power, and cost contingency will be held at the NEXUS project level and managed by the PM or DPM, as appropriate. We propose $18.7M of cost contingency, 25.6 kg of mass contingency, and 26.4 watts of power contingency. In addition to these contingencies, NEXUS has 39.0 kg of mass margin and 39.1 watts of power margin. The NEXUS management team will continuously monitor cost and technical status to facilitate early problem identification and appropriate distribution of contingency. The release of contingency will require CCB approval, once agreed upon allocations are established and placed under configuration control. (For schedule, see F.4.)

F.3.c Acquisition Strategy

NEXUS will use a variety of contract vehicles to obtain maximum science return and superior mission performance. Each of our expected contract vendors has strong experience with GSFC procurement processes.

Deliverables from NRL and UCB will be obtained via cost-reimbursable contracts. Spectrum Astro will be funded via a fixed fee price contract through GSFC's RSDO. Spectrum Astro has already been selected using a competitive procurement process as the S/C partner for the mission. Each contract will include a statement of work, specification, and a deliverable items list, and will require regular cost and technical reporting.

F.4 Project Schedule

The baseline NEXUS schedule is shown in Figure 9. We have identified instrument development as the critical path, beginning with engineering model electronics and mechanism development and test, followed by flight instrument development. Three months of fully funded reserve is built into the critical path activities. This reserve is intentionally tied to instrument and observatory deliveries to provide flexibility in resolving problems during the respective integration and test activities. Spacecraft bus development, while not on the critical path, has 3.5 months of reserve against delivery to observatory I&T. The NEXUS team is well aware of the challenge inherent in developing a SMEX mission to launch readiness within 36 months of selection. In order to achieve the desired August 2007 launch date, the Phase B and early Phase C schedule has been biased toward critical path activities. We plan to conduct a combined System Concept/Requirements Review at the start of Phase B, followed by a mission Preliminary Design Review in January 2005. Separate instrument and mission Critical Design Reviews (CDRs) will facilitate an early start to flight instrument fabrication.

The NEXUS management team understands that schedule performance must be managed and measured with the same attention as technical and cost performance. To facilitate this, a full-time GSFC scheduler/planner will be responsible for developing, statusing and interpreting all schedules. Detailed milestone schedules will be developed for each mission element,

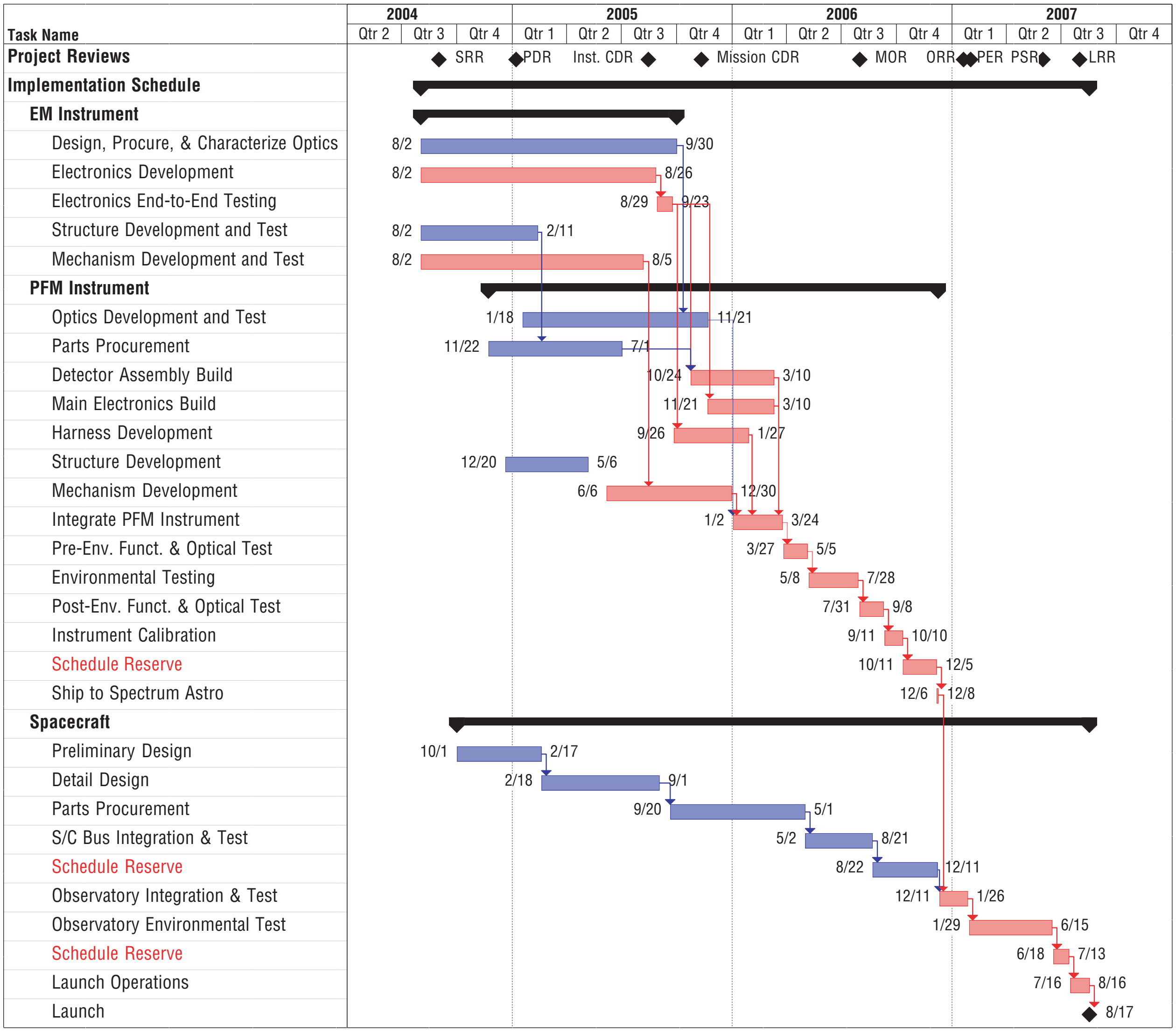


Figure 9: The NEXUS schedule contains ample reserve for instrument and S/C development. Red denotes critical path.

and rolled up into an integrated NEXUS schedule. All schedule activities will be coded with, and tracked against, the proper Work Breakdown Structure (WBS) identification. After Preliminary Design Review (PDR), schedule status will be updated monthly and measured against the established baseline schedule. Any deviations will be identified and corrective actions implemented and monitored until completion.

G COST AND COST ESTIMATING METHODOLOGY

G.1 Cost Overview

The NEXUS Mission will deliver break-through science within the SMEX cost cap of \$120M in FY03 dollars. This includes \$500K for a 5-month Phase A study. We base our costs on a launch readiness date of August 2007, as well as a baseline science mission life of 2 years. Real year dollars have been derived utilizing the NASA New Start Inflation Index as outlined in Table B-6 of the AO. The grass-roots estimate is fully consistent with the most recent full cost accounting guidance as provided by the GSFC Chief Financial Officer.

NASA Headquarters can share our confidence that the proposed costs are reasonable and will remain within the cost cap because the NEXUS Mission requires no technology development, has robust technical, programmatic and cost reserves, and draws on a heritage of successful SMEX missions such as TRACE, WIRE, and SWAS. Our basis of estimates

(BOE) is derived from the cost history of these past missions and incorporates updated vendor quotes and experienced engineering estimates to develop a cost estimate with a high level of confidence. The risk of cost growth is mitigated through the utilization of firm fixed price contracts for the spacecraft and the launch service, augmented with robust cost reserves.

Contributions from GSFC and RAL have allowed us to bolster our cost reserves. NEXUS is considered a high priority mission by GSFC, and the Center will provide contributions toward the mission's civil servant labor to ensure its success. During the Phase A study period, GSFC will provide the equivalent of $0.9M in RY$. During Phases B-E, GSFC will provide civil servant labor in the amount of $1.7M in RY$, for a total GSFC contribution of $2.6M in RY$. RAL will be participating in NEXUS as a partner by providing the calibration and ground station services in the U.K., on a no-exchange-of-funds basis. RAL will provide calibration services in FY06 and ground station services between FY07 and FY09 totaling $1.8M in RY$.

Table B-3 entitled "Total Mission Cost Funding Profile Template for SMEX Investigations" displays these contributions. The GSFC and RAL contributions are included in the total mission costs, but are not part of the total NASA OSS cost as shown in Table B-3. Table B-5, "Mission Phase Summary for NASA OSS Cost," displays the cost profile for NEXUS at a summary level.

The NEXUS proposal team utilized three different approaches to costing this effort, all leading to the same conclusion—NEXUS will be accomplished within the budget and schedule proposed.

G.2 Cost Estimating Methodology

G.2.a Grassroots Cost Estimating

The NEXUS grassroots estimate was developed by a team of experienced project management and engineering personnel who drew upon a heritage of successful in-house missions with similar technical requirements. For work performed in-house at GSFC, the NEXUS team developed realistic estimates of required workforce, travel, and materials from performing organizations. Furthermore, the team worked closely with counterparts at the NRL, UCB and Spectrum Astro to validate requirements and to develop reasonable estimates from partner organizations. The NEXUS management team reviewed the detailed BOE with each performing organization. This effort was useful in identifying areas of overlapping tasks and filling any gaps. All estimates covered formulation, implementation and operations phases.

The grassroots exercise estimated required resources to WBS levels 3 and 4. The included WBS (Figure 10) and WBS Dictionary are defined in sufficient detail to allow accurate projection of manpower and associated resources required to meet programmatic initiatives and schedules. Manpower needs (civil servant and contractor) were estimated by labor classification. Materials and subcontracts were estimated taking into account make or buy decisions, long lead procurements, and information received from proposed partner institutions. Benefit and indirect rates appropriate to each institution were applied to manpower estimates.

The spacecraft will be provided by Spectrum Astro, chosen through a competitive procurement utilizing the GSFC RSDO contract. Spectrum provided a quote consistent with the RSDO catalog price, augmented by mission unique modifications. The mission unique modifications were developed through grassroots estimates and incorporate vendor quotes and recent actual costs for similar S/C components. The S/C costs included in the grassroots estimate are based upon a detailed cost analysis received from Spectrum Astro. The total amount in RY$ without contingency is $30.1M. This includes $250K for the Phase A study as well as $2.3M in RY$ in FY05 for Phase B.

The launch services cost of $29.0M in RY$ is based upon a Pegasus launch vehicle launching from WTR. The costs were received in a memo from Norman M. Beck, Jr. at Kennedy Space Center in guidance provided for this AO.

G.2.b PRICE H Parametric Cost Modeling

A commercially available parametric cost estimating tool was used to support the NEXUS cost estimating effort and to validate the grassroots cost estimate. Working with an analyst from GSFC, trained in the use of the Parametric Review of Information for Costing and Evaluation Hardware (PRICE H) modeling tool available from Price Systems, Inc., we modeled the proposed spacecraft bus and instrument payload. This cost modeling activity was performed independently from our "grassroots" estimate and provides a basis for comparison and validation.

The PRICE H estimate for the observatory development is within 2% of our grassroots estimate (WBS elements 4.0 and 5.0). This relatively small difference between the PRICE H model and the grass roots estimate is further evidence to the high degree of certainty that this proposal can deliver the science at the proposed cost. The included master equipment list for the NEXUS Mission served as the basis for the development of the PRICE H cost model. Note that the model also included $7.8M (FY03$) for observatory I&T, Ground Support Equipment (GSE), environmental test, and launch vehicle integration support in addition to the master equipment list.

G.2.c RAO Parametric Cost Estimating

The GSFC Resource Analysis Office (RAO) also developed an independent parametric cost estimate for the NEXUS Mission. The RAO is an independent office that provides assessments of project life cycle cost and affiliated schedule. Analyses are conducted with analogies and cost models developed by RAO with GSFC historical cost, technical and programmatic data. Parametric cost models are developed with historical data using standard regression techniques. For over 20 years, RAO has collected project cost, programmatic, resource and technical data for NASA missions. The database consists of approximately 400 individual instruments and nearly 50 missions. The ultimate value of a parametric cost model lies in its ability to produce credible and accurate cost estimates. RAO analyzed the proposed investigation by reviewing the programmatic and technical portions of this proposal with the proposal team. The grassroots cost estimate was within 15% of the RAO parametric cost estimate.

G.3 Cost Reserve Strategy

Cost reserve has been carefully allocated by WBS element and fiscal year, considering both the level of maturity of the instrument and spacecraft designs, and the level of risk associated with the different phases of the project. As a result of our risk analysis, we have allocated 30%, or $9.5M in RY$, for instrument development during Phases B-D, and 25%, or $7.5M in RY$, for spacecraft development for Phases B-D. Overall, we have allocated 27% or $20.4M in RY$ to all NASA-funded technical development elements except Phase A, the launch vehicle, E/PO, and Phase E.These levels reflect our commitment to successfully implement the investigation. The GSFC Project Office will hold all cost reserves.

H E/PO, NEW/ADVANCED TECHNOLOGY, AND SMALL DISADVANTAGED BUSINESS

H.1 Education and Public Outreach

NEXUS outreach efforts will focus on middle and high school education in science and engineering. We propose a depth and breadth of activities that will promote science education for students of all backgrounds, capabilities, and skill levels. Our efforts will be done in collaboration with middle and high school teachers with whom we have established excellent working relationships over the years, and will reinforce national science education standards.

Past involvement in such activities includes (1) mentoring teachers during summers to help generate lesson plans; (2) developing and distributing educational material like "How Astronomers Use Spectra to Learn About the Sun and Other Stars," selected as an exemplary resource by the Sun-Earth Connection Education Forum (SECEF) and recommended for wide distribution; (3) visiting classrooms, Boy Scout meetings, Girl Scout meetings, and educator workshops, as well as hosting classes of students; (4) participating in Parents' Night activities; (5) flying a small student payload on the SERTS sounding rocket; and (6) spectroscopy demonstrations.

We will promote a coordinated educational program that extends from middle school through high school in order to continuously engage students in science and engineering activities and experiences.

We will mentor teachers at GSFC and the NRL during summer months. This will help the teachers stay abreast of current developments in science and technology, as well as afford them the opportunity to develop science lesson plans.

We will welcome student participation in internship programs at GSFC and NRL, thereby exposing students first hand to a real world environment on the cutting edge of science and engineering.

We will award NEXUS observing opportunities to classrooms of students on a regular basis, pending favorable review of a "proposal" from that classroom. This could be done in conjunction with English classes, and will foster improvement in student technical writing capabilities. In addition to or as an alternative to the classroom proposal, a follow-up report (e.g., "lab report" or "research paper") might also be expected.

We will develop and/or help develop educational materials, including lesson plans, a portable solar observatory, CDs, and a student-run web site. In particular, we will serve as consultants to the teachers who actually develop the plans. We will purchase one or two reflecting telescopes with clock drives, several filters (H-alpha, Ca II), a projector for displaying images to groups of people, and possibly a digital camera for recording observations as desired. This will enable students to monitor the Sun, and obtain coordinated ground-based observations with NEXUS observations. We will enable students to maintain their own school's NEXUS web site, linked to the main NEXUS web site. This will facilitate an exchange of ideas among students, who will learn from each others' unique experiences as well as from the planned activities. Educational outreach products, student research projects, and representative NEXUS observations will be maintained on the NEXUS web site and made available for distribution on CDs or comparable future technology.

We will support teams of students to participate in interscholastic software and engineering competitions. For students who thrive in a competitive environment, this venue will showcase their best skills and accomplishments.

H.2 New/Advanced Technology

The NEXUS team is fully aware of NASA OSS goals for new and advanced technology transfer and intends to address these goals. During Phase A we will identify any transferable technology that emerges from the study design, and develop plans for satisfying the OSS advanced technology goals.

H.3 Small Disadvantaged Business

The NEXUS Mission and its GSFC leadership team are committed to meeting or exceeding the 8% Small Disadvantaged Business (SDB) subcontracting goal for the NEXUS project. GSFC administers its Small Business (SB) and SDB programs in accordance with the FAR, and its aggressive Socio-Economic Program has allowed it to exceed its 8% SB goal for the last 10 years and its 8% SDB goal for the last 5. An illustrative example of this is the MAP mission, which exceeded the SDB goal by nearly a factor of 2.

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

April 28, 2003

Reply to Attn of: 600

TO: NASA Headquarters
Attn: S/Associate Administrator for Space Science

FROM: 100/Director

SUBJECT: Normal-incidence Extreme Ultraviolet Spectrograph (NEXUS) Proposal

Enclosed is the Normal-incidence Extreme Ultraviolet Spectrograph (NEXUS) proposal in response to NASA's Announcement of Opportunity AO 03-OSS-02. We are very excited about the NEXUS mission, which will revolutionize our understanding of the solar corona. The NEXUS instrumentation will conduct observations that will provide physical insights necessary for the prediction of space weather in the Sun-Earth system, putting this mission at the heart of the Sun-Earth Connection Theme.

The NEXUS mission represents the next generation of spectrograph for solar coronal research. NEXUS is the result of a breakthrough optical design that incorporates new technologies to achieve high optical throughput at high spatial and spectral resolution over a wide field of view in an optimal extreme-ultraviolet spectral band. NEXUS blends solid flight heritage with state-of-the-art innovation to provide a reliable, low-cost, mission for the Explorer Program.

Goddard Space Flight Center has been a world leader in solar spectroscopy for the past 30 years. Much of the technology that has made NEXUS possible has been developed at Goddard and demonstrated on previous orbital missions, and on the Solar Extreme-ultraviolet Research Telescope and Spectrograph (SERTS) sounding rocket instrument.

In conclusion, I assure that the scientific, engineering, management, facility, and other support that is necessary for the on-time and within budget delivery of the NEXUS investigation will be available and committed to the mission. With this understanding, I fully endorse this proposal.

A. V. Diaz

Enclosure

DEPARTMENT OF THE NAVY
NAVAL RESEARCH LABORATORY
4555 OVERLOOK AVE SW
WASHINGTON DC 20375-5320

IN REPLY REFER TO

3910
Ser 7660/012

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

Ladies and Gentleman :

The Naval Research Laboratory acknowledges the identification of Spiro Antiochos, Charles Brown, Kenneth Dere, James Klimchuk, Clarence Korendyke, John Mariska, J. Daniel Moses, John Seely, and Harry Warren as Co-Investigators on the investigation entitled "Normal-incidence Extreme Ultraviolet Spectrometer (NEXUS)," that is being submitted by you in response to NASA Research Announcement of Opportunity 03-OSS-02 (Small Explorers and Missions of Opportunity).

The Naval Research Laboratory is committed to provide the support described in the proposal. Our expected role in the NEXUS project is to provide science support, flight electronics, onboard software and the following mechanisms: front door, fast steering mirror, slit/slot selector, grating focus and detector doors covers. It is understood that the extent and justification of our participation as stated in this proposal will be evaluated during peer review in determining the merits of this proposal.

Should you have any questions, please contact the undersigned.

Sincerely,

HERBERT GURSKY
Superintendent
Space Science Division
By direction of the Commanding Officer

Enclosure: Signed original proposal (NRL proposal # 76-103-03) plus 15 copies

Dr. Joseph Davila,

We acknowledge that we are identified by name as Co-Investigators to the investigation entitled

'Normal-incidence Extreme-Ultraviolet imaging Spectrometer (NEXUS)'

that you are submitting to the NASA Announcement of Opportunity 03-OSS-02, Small Explorers and Missions of Opportunity. We intend to carry out all responsibilities identified for us in this proposal. We understand that the extent and justification of our participation as stated in this proposal will be evaluated during peer review in determining the merits of this proposal.

Dr. Spiro Antiochos

Dr. J. Daniel Moses

Dr. Charles Brown

Dr. John Seely

Dr. Kenneth Dere

Dr. Harry Warren

Dr. James Klimchuk

Dr. Amy Winebarger

Dr. Clarence Korendyke

Dr. Enrico Landi

Dr. John Mariska

SPECTRUMASTRO

15 April 2003

Dr. Joseph M. Davila
Principal Investigator, NEXUS SMEX Project
Goddard Space Flight Center
Mailstop 682.0
Greenbelt, MD 20771

Subject: Spectrum Astro Letter of Endorsement for NEXUS Proposal

Dear Dr. Davila:

I am pleased to endorse Spectrum Astro's participation with full company resources for the design and development of the NEXUS SMEX spacecraft, and to have this unique opportunity to work with you and the NEXUS team to provide critical spectroscopic observations necessary to trace energy flow throughout the solar atmosphere with high spatial and cadence resolution for understanding the variability of the Sun and its effect on the Earth. We look forward to working with Goddard Space Flight Center and the NEXUS team over the course of Phases A, B, C/D, and E. We are convinced that NEXUS is a high quality science mission with great leadership that will provide new and exciting insight into the sun's interaction with the earth.

The Management of Spectrum Astro is fully committed to the success of NEXUS, and we will keep the same team on Phase A that has supported this proposal effort. Further, I want to ensure to you, to the NEXUS Team, and to NASA, that should we be selected for the design and development phases we have in place a staffing plan that assures maximum attention to NEXUS without resource allocation risks to other ongoing programs.

Spectrum Astro is excited about working with the NEXUS Team on a highly successful SMEX mission. Please do not hesitate to call me at (480) 892-8200 if you have any questions. We look forward to a long and rewarding relationship with you and the NEXUS Team.

Sincerely,

Daren Iverson
Vice President and CFO

cc: D. Olschansky
D. Conte
D. Toomey

1440 N. Fiesta Boulevard
Gilbert, Arizona 85233 USA
☎ 480.892.8200 Fax 480.892.2949

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Experimental Astrophysics Group
TEL: (510) 643-1461
FAX: (510) 643-9729

SPACE SCIENCES LABORATORY
BERKELEY, CALIFORNIA 94720-7450

March 6th 2003

Dr. Joseph Davila
Laboratory for Astronomy & Solar Physics
Code 682
NASA Goddard Space Flight Center
Greenbelt Road
Greenbelt, MD 20771
USA

Dear Joseph.

With this letter I wish to endorse the participation of Dr. Oswald Siegmund on the investigation entitled the "Normal Incidence Extreme Ultraviolet Imaging Spectrometer (*NEXUS*)" which is submitted in response to the NASA AO 03-OSS-02 Research Announcement "Small Explorers (*SMEX*) and Missions of Opportunity".

The Space Sciences Laboratory of the University of California, Berkeley is committed to provide the support described in the enclosed Statement of Work. The Co-Investigator, Dr. Oswald Siegmund will carry out all responsibilities identified for him, and his research team, in this proposal. It is understood that the extent and justification of this participation as stated in the proposal will be evaluated during peer review in determining the merits of this proposal.

Sincerely,

Prof. Robert Lin
Director
Space Sciences Laboratory
UC Berkeley

Dr. Oswald Siegmund
Experimental Astrophysics Group
Space Sciences laboratory
UC Berkeley

SPACE SCIENCE & TECHNOLOGY DEPARTMENT
Director, Prof Richard Holdaway FREng.

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Dr Joseph Davila
Code 682
NASA/Goddard Space Flight Centre
Greenbelt
Maryland 20771
USA

22nd April 2003

Dear Dr Davila

NEXUS PROPOSAL FOR THE NASA SMEX OPPORTUNITY

Through this letter I wish to endorse the participation of the Space Science & Technology Department of the Rutherford Appleton Laboratory in the NEXUS mission which is being proposed for the next NASA SMEX (Small Explorer) opportunity.

Specifically, I endorse the participation of Professor Richard Harrison, Dr Jim Lang and Dr David Pike in the NEXUS mission. We are committed to providing support for the mission using the RAL ground station, through the provision of software and through the use of our 'Blue Tank' calibration facility, as described in the NEXUS proposal. The RAL Co-Investigators will carry out all responsibilities identified for them in the proposal. However, it is understood that the extent and justification of this participation will be evaluated during a peer review process, and is subject to the availability of funds after the completion of that process.

Yours sincerely

Richard Holdaway.

Prof Richard Holdaway
Director

cc R Harrison, J Lang, D Pike, RAL

USRA

UNIVERSITIES SPACE RESEARCH ASSOCIATION

Cooperative Program in Space Science

7501 Forbes Boulevard, Suite 206
Seabrook, MD 20706-2253
Tel: (301) 805-8396
Fax: (301) 805-8466

NASA/Goddard Space Flight Center
Mail Code 610.3, Bldg. 2
Greenbelt, MD 20771

24 April 2003

Dr. Joseph M. Davila
NASA/Goddard Space Flight Center
Mail Code 682
Greenbelt, MD 20771

Re: Co-I: Dr. Scott McIntosh
NRA/AO: NASA A03-03-OSS-02
Title: "Normal Incidence Extreme Ultraviolet Spectrometer (NEXUS)"

Dear Dr. Davila:

Universities Space Research Association endorses the participation of Dr. Scott McIntosh as a Co-I on the above proposal entitled "Normal Incidence Extreme Ultraviolet Spectrometer (NEXUS)" in response to NASA A03-03-OSS-02. Should the above proposal be awarded, Dr. McIntosh's Co-I contributions to this project, being consistent with his present duties and responsibilities would be provided at no cost.

Should you require further information or have any questions, please call me at the above number.

Sincerely,

David V. Holdridge
Program Manager
Cooperative Program in the Space Sciences (CPSS)

cc: Scott McIntosh

1.0 INTRODUCTION

This is the Statement of Work for the NEXUS Mission. It is organized into sections that cover each phase of the Mission.

- Section 2.0 is the Phase A SOW
- Section 3.0 is the Phase B SOW
- Section 4.0 is the Phase C/D SOW
- Section 5.0 is the Phase E SOW

2.0 PHASE A STUDY

2.1 Scope of Work

The NEXUS Mission shall provide the personnel, equipment and facilities to perform the analyses required to define the NEXUS science investigation, science payload, spacecraft, science and mission operations concepts, and the ground data systems. The NEXUS Mission shall perform the work required for the Phase A Study as described in the following subsections and document it in the form of a Concept Study Report (CSR).

2.1.1 Science Investigation Definition

The NEXUS team will refine the science investigation and describe it in the CSR. This includes refining the descope options of the baseline mission defined in the proposal. In addition, the science team shall produce a science requirement document.

2.1.2 Education and Outreach

The NEXUS team shall document the education, outreach, technology, and small disadvantaged business plan. This will include education program activities, public awareness, and small disadvantaged business participation in the mission.

2.1.3 Mission Management

The NEXUS team shall document the WBS baseline, cost baseline, and schedule baseline. The Management Plan provided in the proposal shall be refined, costs will be estimated in greater detail, a letter of agreement will be drafted with Rutherford Appleton Laboratory in the United Kingdom, and a Risk Management plan will be generated.

2.1.4 Systems Engineering

The NEXUS team shall document a system engineering plan in the CSR. In addition, the NEXUS team shall also refine the mission design overview from this proposal and describe it in the CSR. This includes requirements flowdown and traceability from the science requirements to the spacecraft, instrument, mission operations, and ground data systems requirements, as well as design implementations. The NEXUS team shall also provide a preliminary orbital debris analysis along with a draft orbital debris mitigation plan.

2.1.5 Mission Design

The NEXUS team shall refine the mission design/ operations concept and describe it in the CSR. The design concept fully describes the operational phase of the mission from launch to end of mission, including data delivery to GSFC. The mission design will include the launch vehicle, mission orbit, observation requirements, data validation requirements, a preliminary mission timeline, and ground station support requirements.

2.1.5.1 Spacecraft Design

The NEXUS team, including Spectrum Astro shall develop a spacecraft design supporting the payload and mission requirements, and shall describe the design in the CSR. The design description will fully identify the spacecraft systems and describe their characteristics and requirements. This will include a description of the flight system design, a block diagram, a summary of the estimated performance, and the flight heritage or rationale used to select the spacecraft subsystems and components. The NEXUS Mission will perform studies and analyses to validate the spacecraft design. This includes, but is not limited to: Target scan analysis; updated integrated thermal analysis; power system analysis and sizing; attitude control system analysis; spacecraft structural design and analysis update; mass optimization; radiation effects analysis; and communications architecture and ground system optimization.

2.1.5.2 Instrument

The NEXUS team shall refine the instrument interface requirements, and provide documentation in the CSR that includes power, mechanical, thermal, command and telemetry, electromagnetic compatibility and contamination requirements. The NEXUS team shall also provide a preliminary instrument integration and test plan in the CSR that will describe the testing of telescope and spacecraft components prior to integration into a single system.

2.1.5.3 Mission Operations and Ground Data System

The NEXUS team shall refine and document the investigation mission operations and ground operations support. This includes the approach for managing mission operations and flight operations support, the ground data system development approach, and ground station support requirements

2.1.6 Product Assurance and Safety

The NEXUS team shall describe the planned product assurance and safety processes which assure that the product meets specifications.

2.2 Deliverables

The NEXUS team shall deliver the following documents in Phase A:

- Phase A Concept Study Report that outlines the technical, cost, and management data required by NASA HQ for the final mission selection.
- Science Requirements Document

2.3 Government Responsibilities

The Government (GSFC) shall provide the Explorer Program Management.

3.0 PHASE B STUDY

3.1 Scope of Work

The NEXUS team shall provide the personnel, equipment and facilities to perform the analyses required to define the NEXUS science investigation, science payload, spacecraft, science and mission operations, and ground data systems. The NEXUS Mission shall provide the personnel, equipment, and facilities required to produce the deliverables defined in Section 3.2 of this appendix.

3.1.1 Science Management

GSFC shall be responsible for providing scientific oversight for the NEXUS mission. The NEXUS PI shall also provide oversight of the implementation of the NEXUS E/PO program, development and implementation of the instrument operations plan, and science data acquisition, calibration, validation and distribution.

GSFC shall define and develop the NEXUS Ground Data System (GDS)/Mission Operations System (MOS) Requirements Document, which will address instrument operation requirements and flight rules.

3.1.2 Project Management

The NEXUS team shall document the WBS baseline, cost baseline, and schedule baseline. A combined Systems Concept/Requirements Review at the beginning of Phase B and a Preliminary Design Review (PDR) will be held at the conclusion of Phase B.

3.1.3 Systems Engineering

The NEXUS team shall establish a systems engineering capability which shall be responsible for integrating the technical efforts of the entire NEXUS development team to ensure that the performance objectives of the Mission are met with minimum risk. This function shall: (1) provide mission requirements traceability; (2) perform trade studies and status assessments to support the management decision making process; (3) support the risk management process by identifying and characterizing risks and developing appropriate risk mitigation approaches; (4) ensure the compatibility of all functional and physical interfaces, both internal and external to the instrument, and verify that designs reflect the requirements for all NEXUS systems elements (hardware, software, facilities, personnel and data); (5) ensure the compatibility of all functional and physical interfaces between the NEXUS instrument and the spacecraft; and (6) be responsible for all necessary systems level engineering activities associated with specialty disciplines which include, but are not limited to, reliability, contamination control, electromagnetic interference, space charging, and radiation effects.

3.1.4 Performance Assurance and Safety

The NEXUS Mission shall establish, implement and maintain a performance assurance and safety program for both hardware and software development that meets all applicable safety requirements. The performance assurance program shall apply to all work performed by GSFC, NEXUS team members, and subcontractors and suppliers.

3.1.5 Education and Outreach

The NEXUS Mission shall initiate educational material development with the education and outreach team members.

3.2 Deliverables

The NEXUS Mission shall provide a combined Systems Concept/Requirements Review package and presentation, and a Preliminary Design Review (PDR) package and presentation to the Explorer Program Office.

3.3 Government Responsibilities

The Government (GSFC) shall provide the Explorer Program Management.

4.0 PHASE C/D

4.1 Scope of Work

The NEXUS team shall provide the personnel, equipment and facilities to perform the analyses required to design, manufacture, integrate and test the NEXUS instrument, spacecraft, and mission operations, and ground data systems and to produce the deliverables defined in Section 4.2 of this appendix.

4.1.1 Science Management

GSFC shall be responsible for providing scientific oversight for the NEXUS instrument. The NEXUS PI shall also provide oversight of the implementation of the NEXUS E/PO program, development and implementation of the suite operations plan, and science data acquisition, calibration, validation and distribution.

GSFC shall define and develop the NEXUS Ground Data System (GDS)/Mission Operations System (MOS) Requirements Document, which will address suite operation requirements and flight rules.

4.1.2 Project Management

GSFC shall establish, implement and maintain a management system which integrates management disciplines (scientific and technical), functions, and systems into an overall activity to achieve cost-effective planning, organizing, controlling, and reporting of the mission objectives. The day-to-day management and administration of the specified work are the prime objectives of this task. As part of this effort, GSFC shall provide traceability of cost, schedule and technical progress data for work being performed by team members and subcontractors in support of this activity.

4.1.2.1 Schedules

GSFC shall establish, implement and maintain a scheduling management function which develops, monitors and maintains the master schedule and derivative detailed schedules for the NEXUS development activities. These schedules shall establish the interrelationships and time-phasing of activities and events essential for the timely and effective implementation of the program, and shall identify critical paths and schedule slack.

4.1.2.2 Reviews

The NEXUS Project will conduct Mission design reviews that will include, as a minimum, the following:

- Instrument Critical Design Review (ICDR);
- Mission Critical Design Review (MCDR);
- Mission Operations Review (MOR);
- Operations Readiness Review (ORR);
- Instrument Pre-environmental Review (IPER);
- Mission Pre-environmental Review (MPER);
- Instrument Pre-shipment Review (IPSR);
- Mission Pre-shipment Review (MPSR);
- Launch Readiness Review (LRR)

4.1.2.3 Risk Management

The NEXUS Mission shall implement and maintain a risk management system which enables the implementation team to minimize the schedule, cost and technical risks while remaining within the resource and programmatic constraints of the mission. As part of risk management, GSFC shall status schedule, cost and technical risk areas of the NEXUS Project and implement necessary mission descopes in accordance with the NEXUS proposal.

4.1.2.4 Configuration Management

The NEXUS Mission shall establish, implement and maintain a configuration management (CM) system for the NEXUS Mission. The CM system shall apply to all work performed by NEXUS team members and suppliers.

4.1.3 Systems Engineering

The NEXUS Mission shall establish a systems engineering capability which shall be responsible for integrating the technical efforts of the entire NEXUS development team to ensure that the performance objectives of the Mission are met with minimum risk. This function shall: (1) provide Mission requirements traceability; (2) perform trade studies and status assessments to support the management decision making process; (3) support the risk management process by identifying and characterizing risks and developing appropriate risk mitigation approaches; (4) ensure the compatibility of all functional and physical interfaces, both internal and external, and verify that designs reflect the requirements for all NEXUS systems elements (hardware, software, facilities, personnel and data); (5) ensure the compatibility of all functional and physical interfaces between the NEXUS instrument and spacecraft; and (6) be responsible for all necessary Mission systems level engineering activities associated with specialty disciplines which include, but are not limited to, reliability, contamination control, electromagnetic interference, space charging, and radiation effects.

4.1.4 Performance Assurance and Safety

The NEXUS Mission shall establish, implement and maintain a performance assurance and safety program for both hardware and software development that meets all applicable safety requirements. The performance assurance program shall apply to all work performed by GSFC, NEXUS team members, and subcontractors and suppliers.

4.1.5 Education and Public Outreach

The NEXUS Mission shall develop and implement an Education and Public Outreach program as defined in the NEXUS E/PO proposal.

4.1.6 Data Acquisition, Processing and Distribution

The NEXUS Mission shall provide the facilities, equipment, services and personnel necessary to acquire, process and distribute NEXUS science data and science data products. NEXUS shall transfer the raw and processed data to the designated archive facility. Deliverable science data products and their delivery schedule shall be as defined in the NEXUS proposal.

4.2 Deliverables

The NEXUS Mission team shall produce the following deliverables:

- CDR Package
- Pre-environmental Review Package
- Pre-ship review Package
- NEXUS Scientific Payload
- NEXUS Spacecraft
- NEXUS Mission Operations and Control Center
- NEXUS Science Data Processing Center
- Education and Outreach materials (films, brochures, Web pages, etc.)

5.0 PHASE E

5.1 Scope of Work

The NEXUS team shall provide the personnel, equipment, and facilities required to operate the spacecraft and science payload during the launch and early orbit phase, in-orbit checkout, acquisition of normal mission mode, and science operations.

5.2 Deliverables

The NEXUS team shall provide the following deliverables:

- NEXUS Level 0 Data
- NEXUS Data Products
- Education and Outreach materials

5.3 Government Responsibilities

The Government (GSFC) shall provide the Explorer Program Management.

JOSEPH M. DAVILA

NASA'S GODDARD SPACE FLIGHT CENTER **PRINCIPAL INVESTIGATOR**

PRESENT POSITION

Astrophysicist, Solar Physics Branch, Laboratory for Astronomy and Solar Physics, NASA's Goddard Space Flight Center, Greenbelt, MD

EDUCATION

1982 Ph.D. Astronomy, University of Arizona
1978 B.S. Physics, University of California, Irvine
1972 B.S. Mechanical Engineering, Lamar University

EMPLOYMENT

1995-Present—Astrophysicist, Solar Physics Branch
1988-1995—Head, Solar Stellar Atmospheres Section, Solar Physics Branch
1984 -1988—Plasma Astrophysicist, Solar Physics Branch
1982-1984—NAS/NRC Research Associate, Solar Physics Branch
1978-1982—Astronomy Research/Teaching Assistant
1972-1976—Engineering Research and Development, Hercules, Inc.
1968-1971—Design Engineer (Co-Op), Texaco, Inc.

AWARDS

2000—NASA Medal for Exceptional Service
1999—Goddard Outstanding Leadership Award
1996—Goddard Group Achievement Award – EUV Optical Technology
1994—Goddard Group Achievement Award – Innovative solar research
1992—NASA Group Achievement Award for SERTS Multilayer grating, grazing-incidence optics
1986—Laboratory for Astronomy and Solar Physics Peer Award
1981—Astronomy Department Tuition Scholarship

HONOR SOCIETY MEMBERSHIPS

Sigma Pi Sigma—Physics Honor Fraternity
Tau Beta Pi—Engineering Honor Fraternity
Pi Tau Sigma—Mechanical Engineering Honor Fraternity

PROFESSIONAL SOCIETY MEMBERSHIPS

American Astronomical Society
American Geophysical Union
American Association for the Advancement of Science
International Astronomical Union

RESEARCH AREAS

Solar and Stellar Physics

Resonance Absorption in inhomogeneous plasmas; Acceleration of high speed wind streams in solar and stellar coronal holes; Plasma heating in closed magnetic structures; EUV spectroscopy; Coronal plasma diagnostics; Solar instrument development

Plasma Physics

Linear and Non-linear theory of hydromagnetic waves; Hydromagnetic instabilities due to energetic particle beams

Cosmic Rays

Acceleration of cosmic rays; Transport of energetic particles within the Galaxy; Modulation of Galactic cosmic rays by the solar wind; Propagation of solar cosmic rays in the interplanetary medium

Publications in Refereed Journals

Davila, J. M., 1985, “A Leaky Magnetohydrodynamic Waveguide Model for the Acceleration of High-Speed Solar Wind Streams in Coronal Holes"”, Ap. J., 291, 328.

Davila, J. M., 1987, “Heating of the Solar Corona by the Resonant Absorption of Alfven Waves", Ap. J., 317, 514.

Davila, J. M., 1988, “A Theory for the Radiation of MHD Surface Waves and Body Waves into the Solar Corona", Ap. J., 332, 1076.

Kumar, C. K., Davila, J. M., and Rajan, R. S., 1989, “The Accretion of Interplanetary Dust by Ap and Am Stars", Ap. J., 337, 414.

Chitre, S. M., and Davila, J. M., 1991, “The Resonant Absorption of p-Modes by Sunspots with Twisted Magnetic Fields", Ap. J., 371, 785.

Davila, J. M., and Chitre, S. M., 1991, “Magnetoacoustic Heating of the Solar Chromosphere", Ap. J. (Lett.), 381, L31.

Davila, J. M., and Thompson, W. T., 1992, “A Rotating Tomographic Imager for Solar Extreme Ultraviolet/Soft X-ray Emission", Ap. J. (Lett.), 389, L91.

Brosius, J. W., Davila, J. M., Thompson, W. T., Thomas, R. J., Holman, G. D., Gopalswamy, N., White, S. M., Kundu, M. R., and Jones, H. P., 1993, “Simultaneous Observations of Solar Plage with SERTS, the VLA, and the Kitt Peak Magnetograph", Ap. J., 411, 410.

Steinolfson, R. S. and Davila, J. M., 1993, “Coronal Heating by the Resonance Absorption of Alfven Waves: The Importance of the Global Mode and Scaling Laws", Ap. J., 415, 354.

Ofman, L., Davila, J. M. and Steinolfson, R. S., 1993, “Coronal Heating by the Resonance Absorption of Alfven Waves: The Effect of Viscous Stress Tensor", Ap. J., 421, 360.

Karpen, J. T., Dahlburg, R. B., and Davila, J. M., 1994, “The Effects of Kelvin-Helmholtz Instability on Resonance Absorption Layers in Coronal Loops", Ap. J., 421, 372.

Davila, J. M., 1994, “Solar Tomography", Ap. J., 423, 871.

Brosius, J. W., Davila, J. M., Thomas, R. J., and Thompson, W. T., 1994, “Solar Coronal Temperature Diagnostics Using Emission Lines from Multiple Stages of Ionization of Iron", Ap. J., 425, 343.

Ofman, L., Davila, J. M. and Steinolfson, R. S., 1994, “Nonlinear Studies of Coronal Heating by the Resonant Absorption of Alfven Waves", Geophys. Res. Lett., 21, 2259.

Ofman, L., Davila, J. M. and Steinolfson, R. S., 1994, “Coronal Heating by the Resonance Absorption of Alfven Waves: Wavenumber Scaling Laws", Ap. J., 444, 471.

Ofman, L. and Davila, J. M., 1995, “Propagation of Alfven Waves, Resonant Heating of Coronal Holes, and its Relation to High Speed Streams", J.G.R., in press.

Ofman, L. and Davila, J. M., 1995, “Nonlinear Resonant Absorption of Alfven Waves in 3-D, Scaling Laws, and Coronal Heating", J.G.R., in press.

Brosius, J. W., Davila, J. M., and Thomas, R. J., 1998, “SERTS-95 Spectral Line Catalogs”, Ap. J. (Supp.), 119, 255.

Ofman, L. and Davila, J. M., 1996, “Nonlinear Excitation of Global Modes”, Ap. J. (Lett.), 456, L123.

Ofman, L., Davila, J. M., and Shimizu, T., 1996, “Alfven Resonance Heating in Coronal Loops”, Ap. J. (Lett.), 459, L39.

Ofman, L. and Davila, J. M., 1997, “Solar Wind Acceleration by Solitary Waves”, Ap. J. (Lett.), 476, L51.

Ofman, L. and Davila, J. M., 1997, “Solar Wind Acceleration”, Ap. J., 476, 357.

Brosius, J. W., Davila, J. M., Thomas, R. J., Saba, J. L. R., and Hara, H., 1997, "Regions Observed with Yohkoh and SERTS", Ap. J., 477, 969.

Falconer, D. A., Davila, J. M., and Thomas, R. J., 1997, "Relative Elemental Abundances of the Quiet Solar Corona as Determined by SERTS", Ap. J., 482, 1050.

Brosius, J. W., Davila, J. M., Thomas, R. J., and White, S. M., 1997, "Coronal Magnetography of a Solar Active Region Using Coordinated SERTS and VLA Observations", Ap. J., 488, 488.

Ofman, L., Klimchuk, J. A., and Davila, J. M., 1998, "A Self-consistent Model for the Resonant Heating of Coronal Loops: Effects of Coupling to the Chromosphere", Ap.J., 493, 474.

Brosius, J. W., Davila, J. M., and Thomas, R. J., 1998, "Calibration of the SERTS-95 Spectrograph from Iron Line Intensity Ratios", Ap. J. (Lett.), 497, L113.

Brosius, J. W., Thomas, R. J., and Davila, J. M., 1999, "SERTS-95 Measurements of Wavelength Shifts in Coronal Emission Lines Across a Solar Active Region", Ap. J., 526, 494.

Reginald, N. L., and Davila, J. M., 1999, "MACS for Global Measurement of the Solar Wind Velocity and the Thermal Electron Temperature During the Total Solar Eclipse on 11 August 1999", Solar Phys., 195, 111

Brosius, J. W., Thomas, R. J., Davila, J. M., and Landi, E., 2000, "Analysis of a Solar Active Region Extreme Ultraviolet Spectrum from SERTS-97", Ap. J., 543, 1016.

Andretta, V, Jordan, S. D., Brosius, J. W., Davila, J. M., Thomas, R. J., Behring, W. E, Thompson, W. T., Garcia, A., 2000, "The Role of Velocity Redistribution in the Enhancing the Intensity of the He II Lambda 304 A Line in the Quiet Sun Spectrum", Ap. J., 535, 438.

Airapetian, V. S., Ofman, L., Robinson, R. D., Carpenter, K., and Davila, J. M., 2000, "Winds from Luminous Late-Type Stars. I: The Effects of Non-linear Alfven Waves", Ap. J., 528, 965.

Falconer, D. A., and Davila, J. M., 2001, "Huge Coronal Structure and Heating Constraints", Ap. J., 547, 1109.

Ofman, L. and Davila, J. M., 2001, "Three-Fluid 2.5-Dimensional Magnetohydrodynamic Model of the Effective Temperature in Coronal Holes" Ap. J., 553, 935.

St. Cyr, O.C., Mesarch, M.A., Maldonado, H.M., Folta, A.D., Harper, A.D., Davila, J.M., and Fisher, R.R., Space Weather Diamond: A Four Spacecraft Monitoring System", J. Atmos. and Sol. Terr. Phys., 62, 1251.

Spiro K. Antiochos

Naval Research Laboratory — **Theory, Numerical Analyst**

Education

B.A. 1970, Mc. Gill University

Ph.D. 1976, Stanford University

Positions Held

2002-present—Adjunct Professor, Dept. Atmospheric, Oceanic, and Space Sciences, University of Michigan

1985-present—Astrophysicist, Space Science Division, Naval Research Laboratory

1980-1985—Senior Research Associate, Center for Space Science and Astrophysics, Stanford University

1978-1980—Research Associate, Institute for Plasma Research, Stanford University

1976-1978—Post-Doctoral Fellow, National Center for Atmospheric Research, Boulder, Co.

Background

Since June 1985, Dr. Antiochos has been an Astrophysicist at the Space Science Division of the Naval Research Laboratory. His field of expertise includes theoretical solar physics and plasma physics. His work consists primarily of developing theoretical models to explain observations, and relies heavily on magnetohydrodynamic (MHD) theory, especially nonlinear equilibria and instabilities, and on large-scale numerical simulations. During his career he has worked on a number of problems related to the Sun and Heliosphere, in particular, the physics of magnetic driven activity and heating, and the structure of the solar corona and transition region. Some of his most widely-recognized contributions are his work on cool loop models for the transition region, on the formation of coronal condensations, on the structure of prominence magnetic fields, and on the "breakout" model for coronal mass ejections and eruptive flares.

Role in NEXUS

Dr. Antiochos will plan observations and will interpret and model the NEXUS data.

Recent Relevant Publications

Antiochos, S.K., "The magnetic topology of Solar Eruptions", 1998, ApJLett, 502, L181

Antiochos, S.K., DeVore, C.R., Klimchuk, J.A., "A model for solar coronal mass ejections", 1999, ApJ, 510, 485

Antiochos, S.K., MacNeice, P.J., Spicer, D.S., Klimchuk, J.A., "The dynamic formation of prominence condensations", 1999, ApJ, 512, 912

Antiochos, S.K., MacNeice, P.J., Spicer, D.S., "The thermal nonequilibrium of prominences", 2000, ApJ, 536, 494

Antiochos, S.K., DeLuca, E.E., Golub, L., McMullen, R.A., "Determination of flare heating and cooling using the Transition Region and Coronal Explorer", 2000, ApJLett, 542, L151

Antiochos, S.K., Karpen, J.T., and DeVore, C.R., "Coronal Magnetic Field Relaxation by Null-Point Reconnection", 2002, ApJ, 575, 578

Antiochos, S.K., Karpen, J.T., DeLuca, E.E., Golub, L., Hamilton, P., "Constraints on Active Region Loop Heating", 2003, ApJ, 590, (in press).

JEFFREY W. BROSIUS

THE CATHOLIC UNIVERSITY OF AMERICA **EPO, DATA ANALYSIS SCIENTIST**

Jeffrey W. Brosius received his B.A. in physics from Franklin and Marshall College, Lancaster, PA, in 1980, and his Ph.D. in physics from the University of Delaware through the Bartol Research Institute, Newark, DE, in 1985. He has been working in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center since September 1985, employed by Raytheon ITSS from September 1985 to February 2002, and by Catholic University since February 2002. Research interests include coronal magnetography, high time resolution spectroscopic observations of coronal transient phenomena, analysis of EUV, X-ray, and radio observations of the Sun, the interaction of nonthermal particle beams with stellar chromospheres, radiative transfer in magnetoactive plasma, theoretical models of the microwave emission from sunspots and loops, and magnetic field extrapolations. He has also published research on cometary plasma tail phenomena and stellar chromospheric emission variability and transition region modeling. He is active in educational outreach, and chaired the SPD Popular Writing Awards Committee from 1999 to 2002. Dr. Brosius is a member of the IAU, the AAS (and its SPD), and the AGU.

SELECTED RELEVANT PUBLICATIONS

"Chromospheric Evaporation and Warm Rain During a Solar Flare Observed in High Time Resolution with the Coronal Diagnostic Spectrometer Aboard the Solar and Heliospheric Observatory": J. W. Brosius, ApJ 586, 1417 (2003).

"Coronal Diagnostics with Coordinated Radio and EUV/Soft X-Ray Observations", J. W. Brosius, in Solar and Space Weather Radiophysics, eds. D. E. Gary & C. O. Keller, Kluwer Academic Publishers (2003).

"Electron Temperature and Speed Measurements in the Low Solar Corona: Results from the June 2001 Eclipse": N. L. Reginald, O. C. St.Cyr, J. M. Davila,& J. W. Brosius, ApJ, submitted (2003).

"Measurements of Three-Dimensional Coronal Magnetic Fields from Coordinated EUV and Radio Observations of a Solar Active Region Sunspot": J. W. Brosius, E. Landi, J. W. Cook, J. S. Newmark, N. Gopalswamy, & A. Lara, ApJ 574, 453 (2002).

"Search for Evidence of Alpha Particle Beams During a Solar Flare Observed by the Coronal Diagnostic Spectrometer Aboard SOHO": J. W. Brosius, ApJ 555, 435 (2001).

"Analysis of a Solar Active Region Extreme-Ultraviolet Spectrum From SERTS-97": J. W. Brosius, R. J. Thomas, J. M. Davila, & E. Landi, ApJ 543, 1016 (2000).

"SERTS-97 Measurements of Relative Wavelength Shifts in Coronal Emission Lines Across a Solar Active Region": J. W. Brosius, R. J. Thomas, J. M. Davila, & W. T. Thompson, Sol. Phys. 193, 117 (2000).

"Calibration of the SERTS-95 Spectrograph from Iron Line Intensity Ratios:" J. W. Brosius, J. M. Davila, & R. J. Thomas, ApJ 497, L113 (1998).

"Coronal Magnetography of a Solar Active Region Using Coordinated SERTS and VLA Observations": J. W. Brosius, J. M. Davila, R. J. Thomas, & S. M. White, ApJ 488, 488 (1997).

CURRENT AND PENDING RESEARCH SUPPORT

Current Support

"Using CDS, EIT, and Coordinated Ground-Based Observations to Measure Coronal Magnetic Fields and to Seek Evidence for Alpha Particle Beams During Solar Flares": NASA SEC SOHO GIP, 70% FTE for PI Brosius during POP 15 July 2002—14 July 2005.

"Extreme Ultraviolet Normal Incidence Spectrograph (EUNIS)": NASA Suborbital program with PI J. M. Davila, 30% FTE for Brosius during POP 1 Oct. 2002—30 Sep 2005.

Pending Support

"Atmospheric Imaging Assembly (AIA)" (this proposal): NASA SDO with PI A. M. Title, TBD FTE for Co-I Brosius during POP ending 30 Sep 2013.

EDUCATION & EXPERIENCE

1965—B. A. Southern Illinois University, Mathematics
1971—Ph. D. University of Maryland, Chemical Physics
1971-1973—NAS-NRC Postdoctoral Research Associate, Naval Research Laboratory
1973-1976—Astrophysicist, Naval Research Laboratory
1976-1978—Senior Scientific Staff, Ball Brothers Research Corp.
1975-present—Physicist, Naval Research Laboratory

RESEARCH AREAS

XUV high resolution spectroscopy, solar spectra, spectra of laser heated plasmas, synchrotron spectroscopy, optics and design of instruments. Fellow, The Optical Society of America, Dr. Brown is the author or co-author of over 120 scientific articles.

SELECTED PUBLICATIONS

"Measurements of Spectrally Integrated Atmospheric Transmittance in the O2 Schmann-Runge Bands and Derived Oxygen Column Densities: 76 km to 102 km," M. S. Longmire, J. -D. F. Bartoe, C. M. Brown, G. E. Brueckner, and R. Tousey, J. Geophys. Res. 84, 1277 - 1558 (1978).

"The Solar Spectrum 3069A - 2095A from the Echelle Spectrograph flown in 1961 and 1964. An Extension of Rowland's Preliminary Table of Solar Spectrum Wavelengths," C. E. Moore, R. Tousey, and C. M. Brown, NRL Report 8653, (Naval Research Laboratory, Washington, D. C. 1982), 169pp.

"Grazing incidence technique to obtain spatially resolved spectra from laser heated plasmas," W. E. Behring, J. H. Underwood, C. M. Brown, U. Feldman, J. F. Seely, F. J. Marshall, M. C. Richardson, and J. H. Underwood, Applied Optics, 27, 2762 - 2766 (1988).

"High Resolution VUV Spectroscopic Facility at the SURF II Electron Storage Ring," M. L. Ginter, D. S. Ginter, and C. M. Brown, Applied Optics 27, 4712 - 4724 (1988).

"Imaging of Laser-Produced Plasmas at 44 A Using a Multilayer Mirror," C. M. Brown, U. Feldman, J. F. Seely, M. C. Richardson, H. Chen, J. H. Underwood, and A. Zeigler, Optics Communications 68, 190 - 195 (1988).

"The Bragg Crystal Spectrometer for Solar-A," J. L. Culhane, E. Hiei, G. Doschek, A. M. Cruise, R. D. Bentley, J. A. Bowles, C. M. Brown, U. Feldman, A. Fludra, P. Guittridge, J. Lang, J. Lappington, J. Magraw, J. Mariska, Y. Ogawara, J. Payne, K. Phillips, P. Sheather, K. Slater, E. Towndrow, M. Trow, and T. Watanabe, Solar Physics 136, 89 - 104 (1991).

"Satellite measurements of hydroxyl in the mesosphere," R. R. Conway, M. H. Stephens, J. G. Cardon, S. E. Zasidil, C. M. Brown, J. S. Morrill, and G. H. Mount, Geophys. Res. Lett. 23, 2093-2096 (1996).

"High-resolution x-ray imaging of planar foils irradiated by the Nike KrF laser." C. Brown, J. Seely, U. Feldman, S. Obenschain, S. Bodner, C. Pawley, K. Gerber, J. Sethian, A. Mostovych, Y. Aglitskiy, T. Lehecka, and G. Holland, Phys. Plasmas 5, 1397-1401 (1997).

"Calibration of an Extreme Ultraviolet Transmission Grating Spectrometer Using Synchrotron Radiation," J. F. Seely, C. M. Brown, G. E. Holland, F. Hanser, J. Wise, J. L. Weaver, R. Korde, R. Viereck, R. Grubb, and D. L. Judge, Applied Optics 40, 1623-1630 (2001).

"The determination of absolutely calibrated spectra from laser produced plasmas using a transmission grating spectrometer at the Nike facility," J. L. Weaver, G. Holland, U. Feldman, J. F. Seely, C. M. Brown, V. Serlin, A. V. Deniz, and M. Klapisch, Rev. Sci. Instr. 72, 108 – 118 (2001).

"High –Resolution Spectroscopy of G91-B2B in the Extreme Ultraviolet," R. G. Cruddace, M. P. Kowalski, D. Yentis, C. M. Brown, H. Gursky, M. A. Barstow, N. P. Bannister, G. W. Frasier, J. E. Spragg. J. S. Lappington, J. A. Tandy, B. Sanderson, J. L. Culhane, T. W. Barbee, J. F. Kordas, and W. Goldstein, Submitted for Publication (2001).

KENNETH P. DERE

NAVAL RESEARCH LABORATORY **NRL PROJECT SCIENTIST**

CURRENT POSITION

Head, Solar Atmosphere Physics Section, Code 7663; Solar Physics Branch, Space Science Division; Naval Research Laboratory, Washington, D.C.

EDUCATION

A.B (1969), M.S. (1971). Cornell University 1969
Ph.D. The Catholic University of America 1980

EXPERIENCE

1971-present—Space Science Division, NRL

RESEARCH INTERESTS

EUV and UV spectroscopic diagnostics of high temperature plasmas such as the solar chromosphere, transition zone, corona and solar flares as a means toward understanding their basic physical processes.

I have analyzed the NRL HRTS ultraviolet spectra to study the fine-scale structure, flows and dynamical activity in the solar transition region. In particular, I have examined the question of unresolved, subresolution structures and velocities in the transition region, the characteristics of explosive events and their relation to magnetic reconnection in flux emergence and cancellation, and outflows in coronal holes.

My interest in magnetic reconnection has led me to examine reconnection rates for relatively large scale solar magnetized plasmas. Dynamical situations are produced by the emergence of new magnetic flux or by the eruption of existing structures. The have been found to reconnect at a rate consistent with a Lundquist number of about 100-10000, roughly 10 orders of magnitude faster than predicted by our knowledge of the classical resistivity in the corona.

Current interests include the analysis of LASCO and EIT data from SOHO. These observations are providing new insights into the ejection of mass and magnetic fields from the Sun and their interaction with the Earth's magnetosphere. Together with an international consortium, I am helping to lead the development of a comprehensive database for the calculation and interpretation of X-ray, EUV and UV spectra, CHIANTI.

SELECTED PUBLICATIONS

HRTS Images of the Solar Chromosphere and Transition Zone, 1986, Ap. J., 305, 947.

Outflows and Ejections in the Solar Transition Zone, 1986, Ap. J., 310, 456.

Ultraviolet Observations of Solar Fine Structure, 1987, Science, 238, 1267.

Discrete Subresolution Structures in the Solar Transition Zone,1987, Solar Phys., 114, 223.

Turbulent Power and Dissipation in the Solar Transition Zone, 1989, Ap. J., 340, 599.

Explosive Events in the Solar Transition Zone, 1989, Solar Phys., 123, 41.

Transition Zone Flows Observed in a Coronal Hole..., 1989, Ap. J. (Letters), 345, L95.

Explosive Events and Magnetic Reconnection in the Solar Atmosphere,1991, JGR, 96, 9399.

Nonthermal Velocities in the Solar Trans. Zone Observed HRTS, 1992, Sol. Phys., 144, 217.

The rate of magnetic reconnection observed in the solar atmosphere, 1996, Ap J, 472, 864.

CHIANTI - An atomic database for emission lines, 1997, A&AS, 125,149.

EIT and LASCO observations of the initiation of a CME, K. P. Dere et al, 1997, Solar Phys., 175, 601.

LASCO and EIT Observations of Helical Structure in CMEs, K. P. Dere et al., 1999, ApJ, 516, 465.

The Preflight Photometric Calibration of the EIT, K. P. Dere, et al., 2000, Solar Phys., 195, 13

CHIANTI - An Atomic Database for Emission Lines, K. P. Dere, et al., 2001, ApJSS, 134, 331.

Richard J. Fitzgerald

NASA's Goddard Space Flight Center — **Project Manager**

Experience

Sept 2002-Present—Mission Manager, Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Mission, NASA's Goddard Space Flight Center, Greenbelt, MD

March 1997-to Sept 2002—Mission Manager, Gravity Recovery and Climate Experiment (GRACE) Mission, Goddard Space Flight Center

Dec 1991-March 1997—Tracking Telemetry and Command Manager, Tracking and Data Relay Satellite, NASA/Goddard Space Flight Center

April 1988-to Dec 1991—Project Engineer, Electronics Engineer, US/UK Joint Surface Ship Torpedo Defense (SSTD) Project, Naval Surface Warfare Center, White Oak, MD

Sept 1985-April 1988—Design Engineer, Electronics Engineer, Influence Mechanisms Branch, Naval Surface Warfare Center, White Oak, MD

Education

May 1990—M.S. Computer Science, Hardware and Systems, The George Washington University, Washington D.C.

August 1985—B.S. Electrical Engineering, University of Maryland, College Park, MD

Training

1996 Graduate of GSFC Project Management Development Emprise (PMDE) (3 year program), 1995-96 Fellow in the Council for Excellence in Government (1 year program), NASA Project Management (80 hr course, July 1996), NASA Cost Estimation and Control of Flight Instruments (4 hr course April 1996), Basic Procurement for Technical Officers (40 hr course, May 1995), NASA Cost Estimating Techniques (4 hr course March 1995), NASA Space Systems WBS Development (4 hr course, June 1995), Goddard Leadership Program (40 hour course, April 1995), Oral Presentation Strategies (16 hr course, September 1994), NASA Source Evaluation Board (40 hr course, April 1994), Understanding Overhead and Other Direct Cost Fixed Rates (24 hr course, March 1994), NASA Systems Engineering (40 hr course, October 1993), NASA Configuration Management Process (16 hr course, November 1994)

Honors & Awards

NASA Letter Of Commendation, Associate Director, Langley Research Center (March 2003),

NASA Exceptional Service Medal Nomination (December 2002);

GSFC Flight Projects Directorate Peer Award Nomination (2002),

U.S. Navy Letter of Appreciation, Project Manager US/UK STTD Project (December 1991);

U.S. Navy Letter of Commendation, Commander Naval Surface Warfare Center (January 1991);

U.S. Navy Letter of Appreciation, Project Manager US/UK STTD Project (January 1991);

U.S. Navy Letter of Appreciation, Commander Naval Surface Warfare Center (1990);

Outstanding Performance Awards (2002,1993,1991,1989);

Quality Step Increase (1991,1989);

Performance Awards (2001,2000,1999,1998,1997,1995,1994[twice],1990);

Special Achievement Awards (1999,1995[twice],1993,1991,1990,1989,1988,1986);

Group Achievement Awards (2003,2002,2001,2000,1999,1996,1995,1993);

Time-Off Awards (2002, 1999);

Eagle Scout (1977)

JOSEPH B. GURMAN

NASA'S GODDARD SPACE FLIGHT CENTER — **DATA CENTER SCIENTIST**

RELEVANT EXPERIENCE

- Designed and implemented data receipt, reformatting, archiving, and network service systems for SMM, SOHO instruments
- Operated Solar Data Analysis Center (1991 – present), which serves multimission solar physics data to the scientific community via the Internet
- Leading Virtual Solar Observatory definition and implementation effort

SCIENTIFIC INTEREST AND ROLE IN THE INVESTIGATION

- Transient events in the open-B corona; initiation of coronal mass ejections
- Ground system, including Science Operations Center, pipeline data processing, and data archiving/accessibility

EDUCATION AND PROFESSIONAL HISTORY

1979—Ph. D., Astrophysics, University of Colorado; Thesis: Vector Magnetic Fields and Sunspot Umbral Models;

1974—M.S., Physics, University of Colorado;

1972—A.B. (mcl), Astronomy, Harvard College,

U.S. Project Scientist for the Solar and Heliospheric Observatory (1998 -); U.S. Deputy Project Scientist for the Solar and Heliospheric Observatory (1996 – 1998; Co-Investigator, Extreme ultraviolet Imaging Telescope (EIT) on SOHO (1989 -), responsible for ground operations, analysis software, data archiving and dissemination

Mission Scientist, TRACE (2002 -)

Project Scientist, Solar Maximum Mission (SMM) (1986-1989); Experiment Manager, SMM UVSP (1986-1989); Science Team Member, Ultraviolet Spectrometer and Polarimeter (UVSP) on the Solar Maximum Mission (1979-1989)

Facility Scientist, Solar Data Analysis Center (SDAC) / SMM Data Analysis Center (1981-)

RELEVANT REFERENCES

"Polar Coronal Jets at Solar Minimum," D. Dobrzycka, S.R. Cranmer, J.C. Raymond, D.A. Biesecker, and J.B. Gurman 2002, Ap.J., 565, 621

"The Right Amount of Glue: Technologies and Standards Relevant to a Future Solar-Terrestrial Data Environment," J.B. Gurman, G. Dimitoglou, R. Bogart, K. Tian, F. Hill, S. Wampler, P. Martens, and A. Davey, 2002, EOS, SH52C-03

"Did I Say Terabyte? I meant Petabyte: Data Archiving in the Era of SDO," J.B. Gurman, 2001, Eos, SP21B-01

RICHARD HARRISON

RUTHERFORD APPLETON LABORATORY, U.K. **RAL LEAD SCIENTIST**

EDUCATION

B.Sc. (Hons),
Ph.D. FRAS

CURRENT POSITION

Band 2 (Individual Merit) Scientist & Head of Solar Physics Group, Principal Investigator for CDS experiment on ESA/NASA Solar & Heliospheric Observatory, Principal Investigator for HI experiment on NASA STEREO mission. Honorary Professor - St Andrews University.

ACADEMIC CAREER

1986 to present, Solar Physicist, Space Science & Technology Dept., RAL;

1985-86, Long Term Visiting Scientist, High Altitude Observatory, Boulder, Colorado; 1983-1984,SERC Research Fellow, Space Research Dept. University of Birmingham, UK;

1983, Ph.D. in solar physics. Space Research Department, University of Birmingham, UK;

Jan 1989, appointed Hon.Visiting Lecturer, Imperial College London;

Oct 1997, appointed Hon. Senior Lecturer, University of St Andrews; Sep 2000, appointed Hon. Professor. University of St Andrews.

Served on numerous committees, including the ESA Solar System Working Group, ESA Solar SBJ Physics Planning Group, the NASA SDO Payload Definition Study, PPARC Research Assessment Panel, European Geophysical Society Council (as Vice President responsible for Solar Terrestrial Sciences) and COSPAR Publication Committee.

Solar physicist, with research interests in mass ejection processes, coronal structure and quiet Sun processes, in particular through the detection, analysis and interpretation of extreme ultraviolet spectra from solar plasmas. Author of 131 full research papers in the refereed literature and published conference proceedings, including a number of invited reviews and book chapters. Expertise in instrument development, management and operation has led to hardware roles in several missions. Co-investigator on the NASA Solar Maximum Mission (1980-1989) and the Transition Region and Coronal Explorer (TRACE; launched 1998). Principal Investigator for the Coronal Diagnostic Spectrometer instrument on the ESA/NASA Solar and Heliospheric Observatory (SOHO; launched 1995). Principal Investigator for the Heliospheric Imager on the NASA STEREO mission (launch 2005). Member of hardware team for Solar-B, and member of ESA Solar Orbiter Study Team.

SELECTED PUBLICATIONS

"The Coronal Diagnostic Spectrometer for the Solar and Heliospheric Observatory," R.A. Harrison, E.C. Sawyer, and 37 co-authors. Solar Phys. 162, 233 (1995).

"Coronal Magnetic Storms: A new perspective on flares and the 'Solar Flare Myth' debate" R.A. Harrison, Solar Phys. 166, 441 (1996).

"A Study of Extreme Ultraviolet Blinker Activity," R.A. Harrison, J. Lang, D.H. Brooks, and D.E. Innes, Astronomy Astrophys. 351, 1115 (1999).

"Emerging Flux and Coronal Heating: Small-Scale Transient Events in the Low Solar Atmosphere," R.A. Harrison, Proc. 9th European Meeting on Solar Physics. ESA SP-448, 531(1999). (Invited Review)

"A spectroscopic study of coronal dimming associated with a coronal mass ejection," R.A. Harrison and M. Lyons, Astron. Astrophys. 358, 1097 (2000).

"Long-Duration Cosmic Ray Modulation from a Sun-Earth LI Orbit," C.D. Pike and R.A. Harrison, Astron. Astrophys. 362, L21 (2000).

"EUV Sprays: Jet-like Eruptive Activity on the Solar Limb," R.A. Harrison, P. Bryans, and R. Bingham, Astron. Astrophys. 379, 324 (2001).

CURRENT POSITION
Senior Staff Scientist, Code 682, NASA's Goddard Space Flight Center

PROFESSIONAL SPECIALTY
Solar and Stellar Atmospheres

EDUCATION
1958—B. S. (Engineering Physics), Washington University
1959—Independent Study (Mathematics), Oxford University, UK
1968—Ph.D. (Physics and Astrophysics), University of Colorado

PREVIOUS POSITIONS
1977-1994—Coordinator, NASA/CNRS Monograph Series on Nonthermal Stellar Atmospheres
1984-1989—Head, Solar Physics Branch, GSFC
1980-1985—Project Scientist, SOT, GSFC
1981-1982—Associate Chief, Laboratory for Astronomy and Solar Physics (temporary/GSFC)
1975-1980—Study Scientist, SOT, GSFC
1974-1975—Chief, Solar Physics Office, (Acting, NASA HQ)
1968-1973—Research Astrophysicist, GSFC
1963-1968—Research Assistant, JILA, Boulder
1959-1963—Lt. USAF with AFOSR

MAJOR PROJECT/SERVICE RESPONSIBILITIES
Co-Investigator on SERTS (Solar Sounding Rocket)
Co-Investigator on SOHO (SUMER Experiment)
Associate Scientist on SOHO (CDS Experiment)

REFEREED PAPERS
K. Wilhelm, and 13 co-authors including S. D. Jordan, "First Results of the SUMER Telescope and Spectrometer on SOHO (I) Spectra and Spectroradiometry," Solar Phys, 170, 75, 1997.

P. Lemaire, and 13 co-authors including S. D. Jordan, "First Results of the SUMER Telescope and Spectrometer on SOHO (II) Imagery and Data management," Solar Phys, 170, 105, 1997.

S. D. Jordan, A. Garcia, and V. Bumba, "Interpreting the Large Limb Eruption of July 9, 1982," Solar Phys, 173, 359, 1997.

P. Lemaire and 8 other Coauthors including S. D. Jordan, "High Resolution Solar Ultraviolet Measurements," Adv. Space Res., 16, # 20, 2249, 1997

V. Bumba, A. Garcia, and S. D. Jordan, "Growth and Destruction of a Large Long-Duration Active-Region Complex and Its Replacement by a Coronal Hole," Astron & Astrophys, 329, 1138, 1998.

D. Falconer, S. D. Jordan, J. Brosius, J. Davila, R.J. Thomas, V. Andretta, and H. Hara, "Using Strong Coronal Emission Lines as Coronal Flux Proxies," Solar Phys, 180, 179, 1998.

V. Andretta, S. D. Jordan, J. Brosius, J. Davila, R.J. Thomas, W. Behring, W. Thompson, and A. Garcia, "The Role of Velocity Redistribution in Enhancing the Intensity of the He II 304C Line in the Quiet Sun Spectrum," Astrophys J., 535, 438, 2000.

V. Andretta, G. Del Zanna, and S. D. Jordan, "The EUV Helium Spectrum in the Quiet Sun: A By-product of Coronal Emission?," Astron & Astrophys, 400, 737, 2003.

S. D. Jordan, and A. Garcia, "The Use of Sunspot Umbral Areas as a Proxy for Solar Irradiance Variation back to 1876," in preparation.

V. Andretta, G. Del Zanna, S. D. Jordan, and J. Brosius, "Formation of the Helium Resonance Lines in Solar Active Regions," in preparation.

EDUCATION

BA Physics, Magna Cum Laude, Kalamazoo College, 1979

Ph.D. Astrophysics, University of Colorado, 1985

POSITIONS HELD

1985-1987—National Research Council Cooperative Research Associate at the Naval Research Lab.

1987-1994—Research Associate, then Senior Research Scientist and Assistant Director at the Center for Space Science and Astrophysics, Stanford University

1994-today—Astrophysicist at the Naval Research Lab.

BACKGROUND

Dr. Klimchuk's scientific research has involved both theoretical and observational investigations of the properties of magnetized astrophysical plasmas, especially those found on the Sun. It has included numerical simulations of MHD and radiating hydrodynamical systems, and the analysis and interpretation of X-ray, UV, visible and microwave radiations. The main goal of his work has been to elucidate the physics of the outer solar atmosphere (i.e. the solar corona, transition region, and chromosphere), including the explosive and terrestrial-relevant phenomena that occur there. Throughout his career, he has emphasized the important link between theory and observation.

ROLE IN NEXUS

Dr. Klimchuk will plan observations, perform data analysis, and compare results with theoretical models.

RECENT RELEVANT PUBLICATIONS

Klimchuk, J.A., "Cross Sectional Properties of Coronal Loops", 2000, Solar Physics, 193, 53

Klimchuk, J.A., Antiochos, S.K., Norton, D., "Twisted Coronal Magnetic Loops", 2000, Ap.J., 542, 504

Watko, J.A., Klimchuk, J.A., "Width variations along coronal loops observed by TRACE", 2000, Solar Physics, 193, 77

Klimchuk, J. A., "Theory of coronal mass ejections", 2001, in Space Weather (Geophys. Monograph 125), ed. P. Song, H. Singer, \& G. Siscoe (Washington: Am. Geophys. Un.), 143

Klimchuk, J.A., Cargill, P.J., "Spectroscopic diagnostics of nanoflare-heated loops", 2001, Ap.J., 553, 440

Matthews, S.A., Klimchuk, J.A., Harra-Murnion, L.K., "Properties of EUV and X-ray Emission in solar active regions", 2001, A&A, 365, 186

Vourlidas, A., Klimchuk, J.A., Korendyke, C.M., Tarbell, T.D., Handy, B.N., "On the correlation between Coronal and lower transition region structures at arcesecond scales", 2001, Ap.J., 563, 374

Demoulin, P., van Driel-Gesztelyi, L., Mandrini, C. H., Klimchuk, J. A., and Harra, L., "The long-term evolution of AR 7978: testing coronal heating models", 2003, ApJ, 586, 592

Dahlburg, R. B., Klimchuk, J. A., and Antiochos, S. K., "Coronal energy re-lease via ideal 3D instability", 2003, Space Sci. Rev., in press

CLARENCE M. KORENDYKE

NAVAL RESEARCH INSTITUTE **NRL LEAD INSTRUMENT SCIENTIST**

BACKGROUND

Dr. Korendyke's principal scientific interest is in following the transport of mass, momentum and energy through the solar atmosphere into interplanetary space using advanced optical telescopes. As assistant project scientist, he played a central role in the development of the LASCO instrument. Dr. Korendyke has also carried out the HRTS sounding rocket program as project scientist under the direction of Dr. Guenter E. Brueckner. He successfully launched four HRTS sounding rockets.

As principal investigator, Dr. Korendyke led the development of the VAULT payload at NRL. The instrument successfully flew in 1999. An improved version of this payload (VAULT 2) was flown in June 2002. This flight produced images of the solar atmosphere of unprecedented quality.

ROLE IN NEXUS

Dr. Korendyke will be the NRL Hardware Scientist. He will have considerable responsibility for the hardware program and ensuring that the NRL provided hardware meets the NEXUS scientific requirements. He will also participate in the planning of scientific observations, and scientific data analysis.

EDUCATION

1984—B.A. Kalamazoo College

1988—M.A. University of Maryland, College Park

1992—Ph.D. University of Maryland, College Park

POSITIONS HELD

1984-present—Research Physicist, Naval Research Laboratory)

RECENT RELEVANT PUBLICATIONS

Korendyke, Clarence M.: "Imaging channeled spectrograph: a high resolution spectrometer providing multiple simultaneous 2-D monochromatic images over a large spectral range", Applied Optics 1988 20, 4187.

Korendyke, Clarence M., Prinz, Dianne K. and Socker, Dennis G.: "Optical design of a near-UV coronagraph for a sounding rocket platform", Optical Engineering, 1994, 33, 479.

Korendyke, Clarence M, Dere, K.P., Socker, D.G., Brueckner, G.E., and Schmeider, B.: "Ultraviolet Observations of the Structure and Dynamics of an Active Region at the Limb", Ap.J. 1995, 443, 869.

Brueckner, G.E., Howard, R.A., Koomen, M.J., Korendyke, C.M., Michels, D.J., Moses, J.D., Socker, D.G., Dere, K.P., Lamy, P.L., Llebaria, A., Bout, M.V., Schwenn, R., Simnett, G.M., Bedford, D.K. and Eyles, C.J. 1995, ""The Large Angle Spectroscopic Coronagraph (LASCO), Visible Light Coronal Imaging and Spectroscopy", Solar Physics 162, 357.

Wang, Y.M., Sheeley, N.R., Jr., Hawley, S.H., Kraemer, J.R., Brueckner, G.E., Howard, R.A., Korendyke, C.M., Michels, D.J., Moulton, N.E. and Socker, D.G.: 1997, "The Green Line Corona and its Relation to the Photospheric Magnetic Field", Ap.J. 485: 419-429.

C.M. Korendyke, A. Vourlidas, J.W. Cook, K.P. Dere, R.A. Howard, J.S. Morrill, J.D. Moses, N.E. Moulton and D.G. Socker, "High resolution imaging of the upper solar chromosphere: First light performance of the very high resolution advanced ultraviolet telescope", Solar Physics 200: 63-73.

THERESE A. KUCERA

NASA's GODDARD SPACE FLIGHT CENTER | **DATA ANALYSIS, EPO SCIENTIST**

EDUCATION

1993—Ph.D. in Astrophysical, Planetary, and Atmospheric Sciences,University of Colorado

1991—M.S. in Astrophysical, Planetary, and Atmospheric Sciences, University of Colorado

1987—B.A. in Physics, Carleton College

POSITIONS HELD

11/01-present—Astrophysicist, Solar Physics Branch, NASA's Goddard Space Flight Center SOHO Deputy Project Scientist and LWS Data Environment Project Scientist.

Continued support of SOHO UV spectrographs CDS and SUMER.

11/95-10/01—Member of SOHO Science Team, Emergent Information Technologies Inc.

Worked at NASA's GSFC in support of SOHO, in particular the SUMER and CDS ultraviolet spectrographs. Conducted research, planned scientific observations, wrote software for science operations and data analysis.

10/93-10/95—National Research Council Resident Research Associate at NASA's Goddard Space Flight Center.

Studied solar flare X-ray and radio emission to test models of flare energy release and particle acceleration.

RECENT PUBLICATIONS

Kucera, T.A., Tovar, M., and De Pontieu, B. 2003, "Prominence Motions Observed at High Cadences in Temperatures from 10,000 to 250,000 K", Solar Physics, 212, 81.

Richardson, I.G., Lawrence, G.R., Haggerty, D.K., Kucera, T.A., and Szabo, A. "Are CME 'interactions' really important for accelerating major solar energetic particle events?", 2003, Geophysical Research Letters, in press.

Kucera, T.A., Crannell, C.J. 2001, "Solar Physics" Encyclopedia of Physical Science and Technology, Academic Press.

Kucera, T.A., Feldman, U., Widing, K.G., and Curdt, W. 2000, "Wavelengths of Forbidden Transitions Arising from Levels Within the Fe+19 2s22p3 Ground Configuration," Astrophys. J., 538, 424.

Kucera, T.A., Aulanier, G., Schmieder, B., Mein, N., and Vial, J.-C. 1999, "Filament Channel Fine Structures in UV Lines Related to a 3-D Magnetic Mode," Solar Physics, 186, 259.

Kucera, T.A., Andretta, V., Poland, A.I. 1998, "Neutral Hydrogen Column Depths in Prominences Using EUV Absorption Features," Solar Physics, 183, 91.

Ofman, L., Kucera, T.A., Mouradian, Z., and Poland, A.I. 1998 "SUMER Observations of the Evolution and Disappearance of a Solar Prominence," Solar Physics, 183, 97.

Wang, H., Chae, J.-C., Gurman, J.B. and Kucera, T.A. 1988, "Comparison of Prominences in H-alpha and He II 304 Å," Solar Physics, 183, 107.

Schmieder, B., Heinzel, P., Kucera, T., and Vial, J.-C. 1998, "Filament Observations with SOHO SUMER/CDS: The Behavior of Hydrogen Lyman Lines," Solar Physics, 183, 97.

Wilhelm, K., Lemaire, P., Dammasch, I.E., Hollandt, J., Schühle, U., Curdt, W., Kucera, T., Hassler, D.M., and Huber, M.C.E. 1998, "Solar Irradiances and Radiances of UV and EUV Lines During the Minimum of the Sunspot Activity in 1996," Astronomy & Astrophysics, 334, 685.

Wiik, J. E., Schmieder, B., Kucera, T., Poland A., Brekke P., and Simnett, G., 1997 "Eruptive prominence and associated CME observed with SUMER, CDS and LASCO (SOHO)," Solar Physics, 175, 411.

ENRICO LANDI

NAVAL RESEARCH LABORATORY **SPECTRAL THEORIST**

EDUCATION

1998—Ph.D. University of Florence, Italy

POSITIONS HELD

2000-present—Research Physicist, ARTEP, Inc. (Working at Naval Research Laboratory)
1999-2000—Post-doc, Max-Planck Institute for Aeronomy, Germany
1995-1999—Contractor, University of Florence, Italy
1995—Contractor, Naval Research laboratory

BACKGROUND

Dr. Landi has worked in the field of EUV and UV spectroscopy of the Sun and stars, since the beginning of his career.

Dr. Landi has participated to the creation and maintenance of the CHIANTI database of atomic data and transition probabilities for the analysis of spectra from optically thin plasmas. CHIANTI is used worldwide for spectroscopic studies of astrophysical sources. Dr. Landi is also responsible for the maintenance and development of the Arcetri Spectral Code.

Dr. Landi has contributed in the development of a new diagnostic technique for simultaneous temperature and density diagnostics of optically thin plasmas. Dr. Landi has also contributed to develop a technique for testing theoretical loop models with observations by means of high-resolution spectroscopy. He has analyzed data from the CDS/SOHO and SUMER/SOHO spectrometers to investigate the structure and dynamics of quiet and active Sun, the origin of the solar wind and physical properties of solar flares.

RECENT RELEVANT PUBLICATIONS

Landi, E., Chiuderi Drago, F, "Solving the discrepancy between the EUV and microwave observations of the quiet Sun", 2003, ApJ, in press

Landi, E, Feldman, U., Innes, D.E., Curdt, W., "Mass motions and plasma properties in the 10 MK flare solar corona", 2003, ApJ, 582, 506

Young, P.R., Del Zanna, G., Landi, E., Dere, K.P., Mason, H.E., Landini, M., "Chianti, an atomic database for emission lines: VI. Proton rates and other improvements", 2003, ApJS, 144, 135

Landini, M., Landi, E., "Models for solar magnetic loops – Paper I: A theoretical model and diagnostic procedure", 2002, A&A, 383, 653

Brkovic, A., Landi, E., Landini, M., Ruedi, I., Solanki, S.K., "Models for solar magnetic loops – Paper II: comparison with SOHO-CDS observations on the solar disk", 2002, A&A, 383, 661

Landi, E., Mason, H.E., Lemaire, P., Landini, M., "SUMER observations of transition region fine structures", 2000, A&A, 357, 743

Landi, E., Landini, M., "Simultaneous temperature and density diagnostics of optically thin plasmas", 1997, A&A, 327, 1230

Dere, K.P., Landi, E., Mason, H.E., Monsignori Fossi, B.C., Young, P.R., "CHIANTI – an atomic database for emission lines", 1997, A&AS, 125, 149

JAMES LANG
RUTHERFORD APPLETON LABORATORY, U.K. **CALIBRATION SCIENTIST**

EDUCATION

1967—BSc, Glasgow University, Scotland
1971—PhD, Glasgow University, Scotland
Honorary Lecturer, Strathclyde University, Scotland

RELEVANT PROFESSIONAL BACKGROUND

2000—Co-I and manager for RAL part of SECCHI experiment for the STEREO mission
1998—Deputy Head, Space Physics Division, Space Science and Technology Department, RAL
1997—Co-I and manager for RAL element of EIS experiment for the Solar-B mission
1995-1998—Deputy Project Director for the UK Cassini Huygens Project, duties included technical and financial monitoring of 14 funded grants (£7m) at 7 UK institutes
1992—Co-I for the CDS experiment on SOHO
1987-1991—Co-I and manager for RAL part of BCS on Yohkoh, Co-I on Yohkoh
1982-1987—Co-I and RAL Project Scientist for CHASE, flown on Spacelab 2 in 1985

RELEVANT EXPERIENCE

I have authored/co-authored many tens of papers both in refereed journals and published conference proceedings as well as reports. Such publications involve both experimental and theoretical papers on atomic physics, papers on technical aspects of laboratory and solar space instrumentation, including the radiometric calibration of laboratory and solar satellite spectrometers as well as papers on the exploitation of solar physics data from Spacelab 2 CHASE, Yohkoh BCS and SOHO CDS payloads.

SCIENTIFIC INTEREST AND ROLE IN THE INVESTIGATION

Using atomic data for solar plasma diagnostics. Radiometric calibration.

SOME RELEVANT PUBLICATIONS

Lang J, Mason HE and McWhirter RWP, 'The Interpretation of the Spectral Line Intensities from the CHASE Spectrometer on Spacelab 2', Sol. Phys. 129, 31-81, 1990.

Lang J, (Special Editor) 'Electron Excitation Data for Analysis of Spectral Line Radiation from Infrared to X-ray Wavelengths: Reviews and Recommendations', Atomic Data and Nuclear Data Tables 57, 1994.

Harrison RA, Lang J, Brooks DH and Innes DE, 'A Study of Extreme Ultraviolet Blinker Activity', Astron. & Astrophys. 353, 1115-1132, 1999.

Lang J, Kent BJ, Breeveld AA, Breeveld ER, Bromage BJI, Hollandt J, Payne J, Pike CD and Thompson WT, 'The Laboratory Calibration of the SOHO Coronal Diagnostic Spectrometer', J Opt. A: Pure and Appl. Opt. 2, 88-106, 2001.

Lanzafame AC, Brooks DH, Lang J, Summers HP, Thomas RJ and Thompson AM, 'ADAS analysis of the differential emission measure structure of the inner solar corona: application of the data adaptive smoothing approach to the SERTS-89 active region spectrum', Astron. & Astrophys. 384, 242-272, 2002.

Lang J, Thompson WT, Pike CD, Kent BJ and Foley CR, 'The Radiometric Calibration of the Coronal Diagnostic Spectrometer', to appear in ISSI Sci. Rep., SR-002, 2002.

Lang J, Kent BJ and Seely JF, 'The Proposed Calibration of Solar B EIS', to appear in ISSI Sci. Rep., SR-002, 2002.

SCOTT WILLIAM MCINTOSH

UNIVERSITIES SPACE RESEARCH ASSOCIATION **DATA ANALYSIS SCIENTIST**

CURRENT POSITION

Feb. 2003 to Present—Research Scientist, Universities Space Research Association, NASA's Goddard Space Flight Center, Greenbelt, MD.

- Analysis of SOHO and TRACE UV/EUV data
- Modeling solar plasma topography through remote sensing.

RELEVANT EXPERIENCE

Feb. 2001 to Feb. 2003—European Space Agency, External Fellow, NASA's Goddard Space Flight Center

- Analysis of SOHO and TRACE UV/EUV data
- Development of Radiation MHD code
- Development of Wavelet analysis techniques for solar data.
- Studying the Self-Organized Criticality

Jan. 1999 to Jan. 2001—Advanced Study Program, Post-Doctoral Fellow, NCAR High Altitude Observatory, Boulder, CO.

- Analysis of SOHO and TRACE UV/EUV data
- Solar UV/EUV remote sensing problems
- Studying MHD wave propagation in the solar atmosphere

EDUCATION

1998—Ph. D. Astrophysics, University of Glasgow, Glasgow, Scotland

Thesis Title: "Optimal Diagnosis of Hot Solar Plasmas"

1995—B. Sc. Mathematics and Physics, University of Glasgow, Glasgow, Scotland

RELEVANT PUBLICATIONS

McIntosh, S. W., Poland, A. I. 2003, "Loop Footpoint Dynamics", Submitted Astrophysical Journal, April 2003.

McIntosh, S. W., Fleck, B., Judge, P. G. 2003, "Investigating the Role of Plasma Topography on Chromospheric Oscillations Observed by TRACE". In Press Astronomy and Astrophysics.

McIntosh, S. W., "Conduction in the Transition Region?: Interpretation of DEMs using SUMER Observations". In ESA Publication "From Solar Min to Max: Half a Solar Cycle with SOHO" (SP-508), May 2002, 271

Mclntosh, S. W., Charbonneau, P., Liu, H. and Bogdan, T. J., Physical Review (E), 65, 46125. "Geometrical Properties of Avalanches in Self-Organized Critical Models of Solar Flares". 2002

Charbonneau, P., Mclntosh, S. W., Liu, H. and Bogdan, T. J., Solar Physics, 203(2), 321, "Avalanche models for Solar Flares" (Invited Review). 2001

Mclntosh, S. W., Bogdan, T. J., Cally, P. S., Carlsson, M., Hansteen, V. H., et al., Astrophysical Journal Letters, 548, 237. "An Observational Manifestation of Magneto-Atmospheric Waves In Inter-network Regions of the Chromosphere and Transition Region". 2001

Mclntosh, S. W., Judge, P. G., Astrophysical Journal, 561, 420. "On the Nature of Magnetic Shadows in the Solar Chromosphere". 2001

Mclntosh, S. W., Astrophysical Journal, 533, 1043. "On the Inference of Differential Emission Measures Using Diagnostic Line Ratios". 2000

Judge, P. G., McIntosh, S. W., Solar Physics, 190, 331. "Non-uniqueness in Atmospheric Modeling". 1999

Mclntosh, S. W., Brown, J. C. and Judge, P. G., Astronomy & Astrophysics, 333, 333. "The Relation Between Line Ratio and Emission Measure Analyses". 1998

JOHN T. MARISKA
NAVAL RESEARCH LABORATORY **DATA ANALYSIS LEAD SCIENTIST**

EDUCATION

1977—PhD Harvard University
1973—AM Harvard University
1972—BA University of Colorado

BACKGROUND

Dr. Mariska's main area of interest is the observational and theoretical study of the structure, dynamics, and radiating properties of the solar transition region and corona. Among his contributions have been studies of transition-region emission measures and density diagnostics, as well as studies of the nonthermal broadening of emission lines formed in the transition region and their implications for models of coronal heating. He has also conducted theoretical examinations of the generation and maintenance of steady flows in magnetic flux tubes under solar conditions, performed numerical studies of solar prominence formation and the early phases of solar flares, and has analyzed UV, EUV, and X-ray data on the features that comprise the outer layers of the solar atmosphere. In recent years, Dr. Mariska has also participated in the development of a new model for predicting the solar EUV and soft X-ray irradiance using solar emission measures. Dr. Mariska has been a PI or Co-I on numerous NASA-sponsored research efforts, and is currently a Co-Investigator on the EUV Imaging Spectrometer for the joint US/Japanese/UK Solar-B satellite. He is the author or co-author of more than 80 articles in the refereed literature and of one book, and is currently a Scientific Editor for The Astrophysical Journal.

Dr. Mariska is currently the head of the Solar Variability Section of the Solar Terrestrial Relationships Branch in the NRL Space Science Division. He is a member of the American Astronomical Society and was Secretary of its Solar Physics Division from 1986 to 1988. He is also a member of the International Astronomical Union, and the American Geophysical Union. He currently serves as Secretary of IAU Commission 12, Solar Radiation and Structure.

ROLE ON NEXUS

Dr. Mariska will serve as the Data Analysis Lead Scientist on NEXUS. In that role, he will be responsible for leading the development of the planning and archiving software, which will be based on that being developed for the Solar-B EIS experiment.

SELECTED RECENT PUBLICATIONS

Warren, H.P., Mariska, J.T., and Wilhelm, K. 1998, High Resolution Observations of the Solar H Lyman Lines in the Quiet Sun with the SUMER Instrument on SOHO, Astrophys J. (Suppl.), 119, 105.

Warren, H.P., Mariska, J.T., and Lean, J. 1998, A New Reference Spectrum for the EUV Irradiance of the Quiet Sun 1. Emission Measure Formulation, J. Geophys. Res., 103, 12077.

Warren, H.P., Mariska, J.T., and Lean, J. 1998, A New Reference Spectrum for the EUV Irradiance of the Quiet Sun 2. Comparisons with Observations and Previous Models, J. Geophys. Res., 103, 12091.

Winebarger, A.R., Emslie, A.G., Mariska, J.T., and Warren, H.P. 1999 Analyzing the Energetics of Explosive Events Observer by SUMER on SOHO, Astrophys. J., 526, 471.

Warren, H.P., Mariska, J.T., and Lean, J. 2001, A New Model of Solar EUV Irradiance Variability: 1. Model Formulation, J. Geophys. Res., 106, 15745.

Doschek, G.A., and Mariska, J.T. 2001, The Physics of the Lower Solar Transition Region, Astrophys. J., 560, 420.

Winebarger, A.R., Emslie, A.G., Mariska, J.T., and Warren, H.P. 2002, Energetics of Explosive Events Observed with SUMER, Astrophys. J., 565, 1298.

Mariska, J.T. 1992, The Solar Transition Region, (Cambridge: Cambridge University Press).

Bentley, R.D., and Mariska, J.T. (eds.) 1996, Magnetic Reconnection in the Solar Atmosphere, Astronomical Society of the Pacific Conference Series, vol. 111.

J. Daniel Moses

Naval Research Laboratory — **CCD Scientist**

Education

B.S., Physics, Duke University, 1975; Ph.D., Physics, University of Chicago, 1985.

Professional

Dr. Moses's areas of interest include observational studies of the structure and dynamics of the solar atmosphere, observational studies of the interaction of the solar atmosphere and the interplanetary medium, and the development of instrumentation to achieve those observations. Among his contributions have been studies of the interrelation of structures of different temperatures and different temporal and spatial scales in the solar atmosphere, studies of plasma parameters and elemental abundances in evolving coronal structures, and studies of the relationship between X-ray properties of flares and interplanetary particle energy spectra. His contributions to instrumentation include development of CCD cameras for space-based solar observations—in the first use of an X-ray CCD in astronomy, investigations of wide-band gap semiconductors for future UV detectors— including the first development of a diamond UV photocapacitor, and the development of calibrations for space-based EUV instrumentation.

Dr. Moses is the Project Scientist for STEREO SECCHI and Deputy Principal Investigator for SDO SHARPP. He has been a PI on four successful NASA suborbital program efforts. He has been a PI or Co-I on numerous NASA and Navy sponsored spaceflight hardware development, data analysis, and advanced instrument development research efforts. He is currently the PI on the EIT CalRoc suborbital calibration program, the PI on the HERSCHEL UV coronagraph suborbital program, the PI on the Navy-sponsored program for the advanced development of CCDs, and a Co-I on the NASA-sponsored program for the development of wideband gap UV solid state detectors. He is an A-level Co-I on the NASA-sponsored EIT and LASCO programs, playing a major role in the development of both instruments, contributing to the operations (particularly for the EIT), and participating in the reduction, analysis and interpretation of the data. Dr. Moses is the author or co-author of more than 40 articles in the refereed literature and proceedings of scientific conferences. He is a member of the American Astronomical Society, the American Geophysical Union, and the American Physical Society.

Selected Relevant Publications

Moses, J.D. et al., "EIT Observations of the Extreme Ultraviolet Sun," Sol. Phys., 175, 571 (1997)

Moses, D., C.M. Korendyke, N. Moulton, J. Newmark, "The Plasma Environment of Prominences - SOHO Observations," proc. of the IAU 167, Aussois, in press (1998)

Berghmans, D., F. Clette, J.D. Moses, "Quiet Sun EUV Transient Brightenings and Turbulence," Astron. and Astrophys., 336, 1039 (1998)

Dere, K.P. et al., "EIT and LASCO Observations of the Initiation of a Coronal Mass Ejection," Sol. Phys., 175, 601 (1997)

Delaboudiniere, J.P. et al., "EIT: Extreme-Ultraviolet Imaging Telescope," Sol. Phys., 162, 291 (1995)

Brueckner, G.E. et al., "The Large Angle Spectroscopic Coronagraph (LASCO)," Sol. Phys. 162, 357 (1995)

Moses, J.D. et al., "Solar Fine Scale Structures in the Corona, Transition Region, and Lower Atmosphere," Astrophys. J., 430, 913 (1994)

Moses, J.D. et al., "A Next Generation EUV Imaging Spectrometer for Solar Flare Observations," SPIE, 2804, 260 (1996)

Moses, J.D. et al., "Performance of EIT Flight Quality Tektronix CCDs in the Extreme Ultraviolet," SPIE, 2006, 252 (1993)

Howard, R.A., B.D. Au, J.F. Hochedez, J.D. Moses, D. Wang, and M.M. Blouke, "Evaluation of Teletronix 1024 MPP Frontside and Backside CCDs," SPIE 1170, 112 (1992)

Marchywka, M. and J.D. Moses, "Diamond MIS Photocapacitor Characteristics," IEEE ED (1994)

LEON OFMAN

THE CATHOLIC UNIVERSITY OF AMERICA — **THEORY, NUMERICAL ANALYST**

EDUCATION

1992-Ph. D.—Plasma Physics, University of Texas at Austin
1988—M. Sc., Plasma Physics, Tel-Aviv University
1986—B. Sc.,Physics, Tel-Aviv University

EXPERIENCE

2001-present—Research Associate Professor, Catholic University of America at NASA GSFC
2000-2002—Visiting Associate Professor, Tel Aviv University
1997-2001—Chief Scientist, Raytheon ITSS Corporation at NASA GSFC
1996-1997—Principal Scientist, Hughes STX Corporation at NASA GSFC
1994-1995—Senior Scientist, Hughes STX Corporation at NASA GSFC
1992-1994—National Research Council Research Associate at NASA GSFC
1989-1992—Research Assistant, University of Texas at Austin
1989-1989—Physicist, Orbot Instruments Ltd., Israel
1984-1988—Research Assistant, Tel-Aviv University
1980-1983—Military Service, Israel Defense Forces, Meteorology unit

SELECTED RECENT PUBLICATIONS

Ofman, L., Gary, S.P., Vinas, A., Resonant Heating and Acceleration of Ions in Coronal Holes Driven by Cyclotron Resonant Spectra, Journal of Geophysical Research, 107, 1461, 2002.

Ofman, L., M. J. Aschwanden, Damping Time Scaling of Coronal Loop Oscillations Deduced from TRACE Observations, The Astrophysical Journal, 576, L153, 2002.

Ofman, L., Wang, T.J., Hot Coronal Loop Oscillations Observed by SUMER: Slow Magnetosonic Wave Damping by Thermal Conduction, The Astrophysical Journal, 580, L85, 2002.

Ofman, L., Thompson, B.J., Interaction of EIT Waves with Coronal Active Regions, The Astrophysical Journal, 574, 440, 2002.

Ofman, L., Davila, J.M., Three-fluid 2.5D MHD Model of the Effective Temperature in Coronal Holes, The Astrophysical Journal, 547, L175, 2001.

Ofman, L., Source Regions of the Slow Solar Wind in Coronal Streamers, Geophysical Research Letters, 27, 2885, 2000.

DAVID PIKE

RUTHERFORD APPLETON LABORATORY, U.K. **DATA ANALYSIS SOFTWARE SCIENTIST**

EDUCATION

B.Sc., Astronomy, University of St Andrews, 1972;
Ph.D., St Andrews/UCSC, 1976.

BACKGROUND

Dr. Pike has been involved in the operations and planning of a number of space missions. He was UK resident astronomer for IUE, based in Madrid, before moving to Japan to oversee the UK BCS operations on the X-ray solar mission, Yohkoh. On his return to the UK, he was appointed software leader for the CDS spectrometer on board SOHO, managing the development of the planning and data analysis software. He has continued to be involved in the operations and planning of that instrument. Currently he is also involved in the design stage for operations and software on both the next Japanese/US/UK mission (Solar-B) and the future European mission Solar Orbiter. Dr. Pike's research interests have involved the use of CDS spectral data to study the dynamics of transition-region features and the long-term evolution of quiet-Sun characteristics monitored by the synoptic observations of SOHO. He is also a member of two major GRID-related projects in the UK, both of which will use GRID technology to improve the access to world-wide solar data. Dr. Pike leads a team in the UK which was awarded a major Public Understanding of Science (Outreach) grant by the astronomy research council to produce an educational CDROM and web site for secondary school children, which will explain current research on the Sun in the context of the physics taught in schools at that level.

SELECTED PUBLICATIONS

"EUV Spectroscopic Observations of Spray Ejecta from an X2 Flare," Pike, C.D. and Mason, H.E. Solar Phys. submitted (2002).

Off-limb EUV Line Profiles and the Search for Wave Activity in the Low Corona Harrison, R.A., Hood, A.W., Pike, C.D. 2002 Astron. Astrophys. Submitted.

"Radiance of Solar Spectral Lines Observed CDS and SUMER on SOHO," A. Pauluhn, I. Ruedi, S.K. Solanki, J. Lang, C.D. Pike, U. Schuehle, W.T. Thompson, and M.C.E. Huber, Astron. Soc. Pacific Conf. Ser. 223, 721 (2001).

"Solar Si XI Line Ratios Observed by the Normal Incidence Spectrometer on SOHO/CDS." J. Lang, D.H. Brooks, M.G. O'Mullane, C.D. Pike, H.P Summers, W.T. Thompson, Solar Phys. 201, 37 (2001).

"Long-Duration Cosmic Ray Modulation from a Sun-Earth LI Orbit," C.D. Pike. and R.A. Harrison, Astron. Astrophys. 362, L21 (2000).

"Variation of Thermal Structure with Height of a Solar Active Region Derived from SOHO CDS and Yohkoh BCS Observations," A. Sterling, C.D. Pike, H.E. Mason, T. Watanabe, S.K. Antiochos, Astrophys. J. 524, 1096 (1999).

"Intercalibration of SUMER and CDS on SOHO. I. SUMER Detector A and CDS NIS," A. Pauluhn, I. Ruedi, S.K. Solanki, J. Lang, C.D. Pike, U. Schuele, W.T. Thompson, and M.C.E. Huber, Applied Optics 38, 7035 (1999).

"Electron Density and Temperature Structure of Two Limb Active Regions Observed by SOHO CDS," H.E. Mason, E. Landi, C.D. Pike, PR. and Young, Solar Phys. 189, 129 (1999).

"Rotating Transition Region Features Observed with the SOHO Coronal Diagnostic Spectrometer." C.D. Pike and H.E. Mason, Solar Phys. 182, 333 (1998).

ARTHUR I. POLAND

NASA'S GODDARD SPACE FLIGHT CENTER **GSFC PROGRAM SCIENTIST**

EXPERIENCE

1999-present—Assistant (part time) to the NASA Chief Scientist at NASA Headquarters (HQ); Senior Project Scientist for the LWS program. I took over this position again when the person I had handed it off to left for a position at NASA HQ. I had left the position to spend more time on my research.

- Other
  - Basic Research (at Goddard Space Flight Center)
  - Theoretical l modeling of energy balanced, radiative transfer, hydrodynamic models of magnetic loops in the solar corona
  - Analysis of spectral data from the Solar and Heliospheric Observatory (SOHO) spacecraft
  - Keynote speaker at the Maine State science and math. teachers association meeting.
  - Many presentations to high schools and middle schools on science.
  - Presentations at various national and regional meetings of the National Science Teachers Association.
  - Worked in various NASA sponsored science teacher workshops. My goals have been to help teachers by giving them a better understanding of physics and what teaching aids and material are available through NASA.

1999-2001—Senior project scientist for the LWS program.

1985-1998—NASA Project Scientist for Solar and Heliospheric Observatory (SOHO)

1980-1985—Astrophysicist at GSFC and scientist on the Solar Maximum Mission (SMM). Developed a research program to study solar flares and prominences.

1969-1980—Scientist at the National Center For Atmospheric Research (NCAR), High Altitude Observatory (HAO) division.

- Did basic research in non-LTE radiative transfer, solar prominences, and the solar corona.
- Team scientist on the HAO White Light Coronagraph experiment on Skylab.
- Worked with another scientist on developing a new solar coronagraph for Mauna Loa Hawaii.

1964-1969—Graduate student in Astrophysics at Indiana University. Received a PhD in 1969.

1961-1964—Undergraduate student in Astronomy at the University of Massachusetts. Received a BS in 1964.

POSITIONS HELD

1969-1980—Research Scientist, National Center for Atmospheric Research; Skylab Coronal Research; Solar Structure Research

1980-present—Astrophysicist, NASA, Goddard Space Flight Center; Research with Solar Maximum Mission Spacecraft

RECENT PUBLICATIONS

Temperature Dependence of UV Line Average Doppler Shifts in the Quiet Sun, J. Chae, H.S. Yun, and A.I. Poland, Astrophysical Journal Supp. vol 114 #1, Jan 1998.

Kucera, T.A., Andretta, A., Poland, A.I., Neutral Hydrogen Column Depths in Prominences Using EUV Absorption Features, Solar Physics (in press) 1999

Ofman, L., Kucera, T.A., Mouradian, Z., and Poland, A.I., Sumer Observations of the Evolution and the Disappearance of a Solar Prominence, Solar Physics, 183, 97, 1998

Poland, A., The SOHO Mission, AGU Geophysical Monography Series, Vol. 109, Burch & Antiochos Eds. 1999

Jungchul Chae, Arthur I. Poland, and Markus J. Aschwanden, Coronal Loops Heated by MHD Turbulence: I. A Model of Isobaric Quiet Sun Loops with Constant Cross-sections, ApJ 581,726, 2002

Chapter in Annual Review of Astronomy and Astrophysics: The New Solar Corona, Markus J. Aschwanden, Arthur I. Poland, and Douglas M. Rabin, Annual Review of Astronomy and Astrophysics, V 39, p175, Annual Reviews, 2001

Douglas M. Rabin

NASA's Goddard Space Flight Center — **GSFC Project Scientist**

Current Position

2000-Present—Head, Solar Physics Branch, Laboratory for Astronomy and Solar Physics, NASA's Goddard Space Flight Center, Greenbelt, Maryland

Recent Experience

2002—Acting Associate Chief, Laboratory for Astronomy and Solar Physics
1996-1997—Acting Director, National Solar Observatory
1992-2000—Associate Astronomer with Tenure, National Solar Observatory

Education

1980Ph.D. (Astronomy), California Institute of Technology
1973 A.B. magna cum laude with highest honors in Astronomy,
Harvard College

Recent Professional Activities

2003—Sun-Earth Connection Advisory Subcommittee (SECAS) (NASA)
2001—Deputy Project Scientist, Solar Radiation and Climate Experiment (NASA)
2001-2002—Management Operations Working Group for Solar Physics (NASA)
2000—National Solar Observatory Users Committee (NSF)

Research Interests

- Structure and dynamics of the outer solar atmosphere
- Properties of magnetic flux concentrations in the photosphere
- Ultraviolet and infrared instrumentation

Selected Publications

Aschwanden, M. J., Poland, A. I., and Rabin, D. M. 2001, "The New Solar Corona," Annual Review of Astronomy and Astrophysics, 39, 175.

Rabin, D. M. 2000, "Fibrils," in Encyclopedia of Astronomy and Astrophysics, Institute of Physics Publishing (online at www.ency-astro.com).

Rabin, D. M. 1997, "The Solar Magnetic Field in Three Dimensions," Solar Physics, 174, 281.

Ayres, T. R., and Rabin, D. M. 1996, "Observations of Solar Carbon Monoxide with an Infrared Imager. I. Thermal Bifurcation Revisited," Astrophysical Journal, 460, 1042.

Rabin, D. M., Jefferies, J. T., and Lindsey, C. (eds.). 1994, Infrared Solar Physics, Proceedings of International Astronomical Union Symposium 154, Kluwer Academic Publishers, 608 pp

O. C. St. Cyr

NASA's Goddard Space Flight Center **MOC Scientist**

Brief Summary of Recent Experience

Dec 2002-present—Astrophysicist, Solar Physics Branch, NASA-GSFC. Senior Project Scientist for NASA's Living With a Star Program.

January 2000-Dec 2002—Research Associate Professor, Department of Physics, The Catholic University of America, Washington, D.C. Co-investigator for the COR1 internally-occulted coronagraph for STEREO. Science Lead for the STEREO Science Center; Deputy Project Scientist; and Co-investigator for the S/WAVES radio burst instrument. Spectroscopic measurements of Sun's corona during total solar eclipses.

October 1995-December 2000—Senior Physicist at Computational Physics, Inc.

Lead Operations Scientist for the Naval Research Laboratory's Large Angle Spectrometric Coronagraphs (LASCO) onboard SOHO (Solar and Heliospheric Observatory).

November 1991-October 1995—Senior Scientist for Engineering Systems Development, Allied Signal Technical Services Corp., Goddard Space Flight Center, Greenbelt, Maryland.

February 1984-November 1991—Chief Observer for the Coronagraph, Solar Maximum Mission. Employed by the High Altitude Observatory.

Education

1985—Ph.D. in Astronomy, University of Florida, Gainesville

1975—B.S. in Astrophysics, University of Oklahoma, Norman

Recent Bibliography

Reginald, N.L., O.C. St. Cyr, J.M. Davila, and J. Brosius, Spectroscopic measurements of the Sun's corona during the June 21, 2001 total solar eclipse, submitted to Astrophysical Journal.

St.Cyr, O.C., and J.M. Davila, The STEREO space weather beacon, in Space Weather Chapman Conference Proceedings, editors P. Song and G. Siscoe, Geophysical Monograph 125, 205-209, 2001.

St.Cyr, O.C., et al., Properties of coronal mass ejections: SOHO LASCO observations from January 1996 to June 1998, Journ.Geophys.Res., 105, 18,169-18,185, 2000.

St.Cyr, O.C., M.A. Mesarch, H.M. Maldonado, D.C. Folta, A.D. Harper, J.M. Davila, and R.R. Fisher, Space Weather Diamond: A four spacecraft monitoring system, Journal of Atmospheric and Solar-Terrestrial Physics, 62, 1,251-1,255, 2000.

St.Cyr, O.C., L. Sanchez-Duarte, P.C.H. Martens, J.B. Gurman, and E. Larduinat, SOHO ground segment, science operations, and data products, Solar Physics, 162, 39-59, 1995.

Dr. Seely joined the Naval Research Laboratory in 1977 where he is presently Head of the UV and X-Ray Spectroscopy Section in the Space Science Division. He has done work in the areas of XUV and X-ray spectroscopy of laboratory and solar plasmas with applications to the diagnosis of these plasmas. His work on solar flare plasmas includes the analysis of spectra and images from the SOHO, Yohkoh, Skylab, and P-78 spacecraft. His work on laboratory plasmas includes the study of high-resolution XUV spectra from laser-produced and tokamak plasmas. Dr. Seely is the Principal Investigator for ONR, NASA, DOE, and NOAA projects for the design, fabrication, and utilization of spectroscopic instrumentation for laboratory, solar, and astrophysical studies. Dr. Seely has led a program for the design and implementation of multilayer-coated gratings and mirrors for the EUV, XUV, and soft x-ray regions and has studied the optical properties of materials in these regions. He is presently developing the multilayer optics for the EIS/Solar-B spectrometer. Dr. Seely holds six U.S. patents. Dr. Seely is the author or co-author of over 190 papers in refereed scientific journals.

EDUCATION

1973—PhD, Dept. of Physics, University of Tennessee
1968—BS, Dept. of Physics, North Carolina State Univ.

EXPERIENCE

1983-Present—Space Science Division, NRL
1977-1983—Optical Sciences Division, NRL
1976-1977—University of Alabama, Huntsville
1974-1976—University of Southern California
1973-1974—Oak Ridge National Laboratory

RECENT PUBLICATIONS ON MULTILAYER EUV GRATINGS AND OPTICS

Seely, J. F., Kowalski, M. P., Cruddace, R. G., Heidemann, K. F., Heinzmann, U., Kleineberg, U., Osterried, K., Menke, D., Rife, J. C., and Hunter, W. R. 1997, “Multilayer-Coated Laminar Grating with 16% Normal-Incidence Efficiency in the 150 Å Wavelength Region,” Appl. Opt. 36, 8206.

Seely, J. F., Goray, L. I., Hunter, W. R., and Rife, J. C. 1999, “Thin-Film Interference Effects on the Efficiency of a Normal-Incidence Grating in the 100-350 Å Wavelength Region,” Appl. Opt. 38, 1251.

Seely, J. F., Watanabe, T., Harada, T., Rife, J. C., and Hunter, W. R. 1999, “Normal-Incidence Efficiencies of 4800 g/mm Ruled Replica Gratings with Multilayer and Gold Coatings in the 125-325 Å Wavelength Region,” Appl. Opt. 38, 1920.

Seely, J. F., Montcalm, C., and Bajt, S. 2001, “High-Efficiency MoRu/Be Multilayer Grating Operating near Normal Incidence in the 11.1-12.0 nm Wavelength Range,” Appl. Opt. 40, 5565 (2001).

Goray, L. I. and Seely, J. F. 2002, “Efficiencies of Master, Replica, and Multilayer Gratings for the Soft X-Ray – Extreme Ultraviolet Range: Modeling Based on the Modified Integral Method and Comparisons with Measurements,” Appl. Opt. 41, 1434.

Seely, J. F., Uspenskii, Yu. A., Pershin, Yu. P., Kondratenko, V. V., and Vinogradov, A. V. 2002, “Skylab 3600 groove/mm Replica Grating with a Scandium-Silicon Multilayer Coating and High Normal-Incidence Efficiency at 38 nm Wavelength,” Appl. Opt. 41, 1846.

Sae-Lao, Benjawan, Bajt, Sa_a, Montcalm, Claude, and Seely, John 2002, “Performance of normal-incidence Molybdenum/Yttrium multilayer-coated diffraction grating at a wavelength of 9 nm,” Appl. Opt. 41, 2394.

Seely, J. F. 2002, “Extreme Ultraviolet Thin-Film Interference in an Al-Mg-Al Multiple-Layer Transmission Filter,” Appl. Opt. 41, 5979.

Oswald H. Siegmund

University of California, Berkeley **Detector Scientist**

Education

1982—PhD in Astronomy & Physics, University College London.
1977—BSc Physics & Astronomy, University of Sussex

Positions

1995—Associate Director, Space Sciences Laboratory, U.C. Berkeley
1996-99—Adjunct Full Professor, U.C. Berkeley Astronomy Dept.
1995—Senior Space Fellow, Space Sciences Laboratory, U.C. Berkeley
1989-1994—Senior Fellow, Space Sciences Laboratory, U.C. Berkeley

Activities

Dr. Siegmund has undertaken the research and development of microchannel plate imaging devices, proportional counters, and scintillators for over 20 years, and participated in more than 40 space-flight instruments. During this time Dr. Siegmund has performed fundamental research into the development of gas proportional counters, X-Ray – visible photocathodes, thin film filters, microchannel plates, electronic readout anodes and electronics, open and sealed tube devices.

PI for 25+ funded technology research programs in the general area of sensors, MCP's, photocathodes, image readouts, and electronics.

PI (US) FUVITA, UV imaging instrument on Spectrum X-gamma

Co-I on the following missions, SOHO satellite, UVCS, SUMER and CDS, Extreme Ultraviolet Explorer Satellite, ALEXIS small satellite, COS HST FUV Spectrometer Instrument, GALEX Small Explorer Satellite, Far Ultraviolet Spectroscopy Explorer Satellite

Associated Scientist, IMAGE (EUVI, SI, WIC) Midex Satellite Program

Instrument developer for SAMPEX, ACE, ROSETTA (ALICE, RTOF), TIMED, EXOSAT, TERRIERS, ORFEUS/ASTROSPAS, FAUST, CHIPS, Pluto-Kuiper, SPEAR, and >25 rockets (in collaboration with Boston U. U. Colorado, GSFC, U. Michigan, SWRI, JHU, U. Wisconsin,)

Professional Services and Awards

Task Group on Technology in NASA, OSS, National Academy of Sciences, 1998-2000
Lawrence Berkeley Laboratory, Engineering Division Review Committee member 3/00
Goddard Space Flight Center, UV Branch Review Committee member 3/00
NASA UV - Visible Branch, UVMOWG member 1994 - 1995
STIS & AXAF peer review committee member, NASA HQ, June 1994
Conference chair/organizer for SPIE conferences on UV instruments, over the last 14 years
Consultant and co-author, "Voyage Through The Universe", Time-Life books, 1991.
Course lecturer, graduate summer school, L' Aquila, Italy, 9/92.
H.S.W. Massey Research Prize, University College London, 1979 -1980
Invited research scientist, GANIL, French national heavy ion accelerator, 4-5/89
Instrument development of the year award, Space Astrophysics Group, UCB, 1990
NASA Goddard Space Flight Center, 7 Achievement Awards, FUSE, 1994 - 2002

Recent publications: (over 170 publications)

O. H. W. Siegmund, A. S. Tremsin, C. P. Beetz, Jr., R. W. Boerstler, D. R. Winn, "Progress on development of silicon microchannel plates", SPIE Proc., vol. 4497, 139-148, 2001

O. H. W. Siegmund Advances in microchannel plate detectors for UV/visible Astronomy, Proc. SPIE Vol. 4854, 2002

O.H.W. Siegmund, A. S. Tremsin, J. V. Vallerga, R. Abiad and J. Hull, High resolution cross strip anodes for photon counting detectors, Nuclear Instruments and Methods in Physics Research (sect. A), 2002

O.H.W. Siegmund*, Anton. S. Tremsin and John. V. Vallerga, Advanced MCP Sensors for UV/visible Astronomy and Biology, Nuclear Instruments and Methods in Physics Research (sect. A), 2002.

ROGER J. THOMAS

NASA'S GODDARD SPACE FLIGHT CENTER **OPTICAL SCIENTIST**

EDUCATION

1970—PhD, Astronomy, University of Michigan
1964—BS, Physics, University of Michigan
1966—MS, Astronomy, University of Michigan
1970—PhD, Astronomy, University of Michigan

RESEARCH EXPERIENCE

My PhD research involved studies of solar X-radiation as measured by UM's soft X-ray photometer on the Orbiting Solar Observatory satellite, OSO-3. At NASA's Goddard Space Flight Center, I analyzed solar XUV spectroscopy data from GSFC experiments on OSO-3 and OSO-5. I became a Co-Investigator for the GSFC `EUV & X-ray Spectroheliograph' on OSO-7 in 1970, and for four sounding rocket instruments: the `Solar EUV Rocket Telescope and Spectrograph (SERTS)' in 1979, the `EUV Normal-Incidence Spectrograph (EUNIS)' in 1999, the `Multi-Order Solar EUV Spectrograph (MOSES)' in 2001, and the `Solar Ultraviolet Magnetograph Investigation (SUMI)' in 2002. I provided optical designs for all of these rocket experiments, as well as for the `EUV Imaging Spectometer (EIS)' on the Solar-B mission selected in 1999. In 1986, I became a Co-I for two major instruments on the Solar and Heliospheric Observatory (SoHO) mission: the `Coronal Diagnostic Spectrometer (CDS)' and `Solar UV Measurements of Emitted Radiation (SUMER)'. I have been Principal Investigator for a number of technical development projects, including `Computer Controlled Polishing of Grazing-Incidence Optics' and `Multilayer Coatings for Solar EUV Optics'. My experience in scientific administration includes being the OSO Project Scientist (1976-1983), the Study Scientist for NASA's Solar Cycle and Dynamics mission (1978-1981), the Deputy Chief of NASA's Solar and Heliospheric Physics Office (1983-1984), and the Deputy Project Scientist for NASA's Orbiting Solar Laboratory mission (1990-1992). To date, I have authored or co-authored 66 scientific publications in refereed journals, as well as 128 other scientific or technical papers.

CURRENT RESEARCH INTERESTS

I am presently pursuing research on the solar corona, active regions, and flares through procurement and analysis of X-ray and EUV observations from space-borne instrumentation. In recent years, I have concentrated on studies of spatially imaged high-resolution EUV spectra of various coronal structures. Specific topics of interest include determination of elemental abundances and their possible variations, investigation of proposed coronal heating mechanisms, and quantitative characterizations of physical plasma conditions in different solar features. In addition, I continue to be actively involved in the design, ray-trace optimization, fabrication, and calibration of XUV optical systems including grazing-incidence telescopes, normal-incidence toroidal gratings, variable line-space gratings, and EUV multilayer coatings.

SELECTED PUBLICATIONS

R.J. Thomas, "Underflight Calibration of SOHO CDS by SERTS-97", ISSI Scientific Research Series: The Radiometric Calibration of SOHO, 225-234, 2002.

R.J. Thomas, "Toroidal Varied Line-Space (TVLS) Gratings", Proceedings SPIE, 4853, 411-418, 2003.

A.K. Bhatia, R.J. Thomas, & E. Landi, "Atomic Data and Spectral Line Intensities for Ne~III", Atomic Data & Nuclear Data Tables, in press, 2003.

R.J. Thomas, "SOHO/CDS Measurements of Coronal EUV Polarization above the Limb", Proceedings, 3rd International Solar Polarization Workshop, Tenerife, Spain, in press, 2003.

Barbara J. Thompson

NASA's Goddard Space Flight Center — **Data Analysis Scientist**

Professional Positions

Aug 1998-present—Astrophysicist, Solar Physics Branch, NASA's Goddard Space Flight Center

Apr 1996-Aug 1998—Research Scientist, Space Applications Corporation at NASA's GSFC

Education

June 1996—Ph.D, Physics, University of Minnesota, Minneapolis, MN

May 1991—B.A., Mathematics and Physics, University of Pennsylvania, Philadelphia, PA

Research Interests

Analysis and interpretation of solar/terrestrial data sets pertaining to coronal structure and solar events which impact the heliosphere and geospace; coordinated observations of solar and heliospheric phenomena involving earth-based and spacecraft observatories; studies of solar coronal dynamics and heating.

Instrument/Mission Involvement

Served as a team scientist or Co-I on over 10 instrument investigations (e.g. SMEX, MIDEX) or proposals, including:

- Project Scientist, Solar Dynamics Observatory (SDO)
- Co-investigator on the STEREO SECCHI and PLASTIC investigations
- Participated in development and launch of the SERTS rocket (1999-2000).
- Assisted in the development of the SPARTAN experiment flown on STS-5, November 1998.
- Served as an operations scientist for the SOHO and TRACE missions, 1996-2002.
- Co-Investigator on proposals developed for the ESSEX, TRIANA, ISIS and NEXUS investigations.

Scientific Leadership and Service

- Co-Chair of the Sun and Heliosphere Division of the IUGG/IAGA (International Union of Geophysics and Geodesy / International Association for Geophysics and Aeronomy), term running from 2003-2007.
- Served on the Living With a Star program's Scientific Architecture Team and the Solar Dynamics Observatory's Science Definition Team, science advisor to the LWS Targeted Research & Technology Team.
- Member of the Solar Physics Division (SPD) of the American Astronomical Society Nominating Committee, 2002.
- Part of the team that developed an innovative concept for coordinated data analysis workshops (CDAWs) called "CDAW in a Box." Leader of the CDAW science workshops and the web site development.
- Served on the NOAA Space Environment Center's "Stakeholder" team, 2002.
- SOHO representative to the International Solar-Terrestrial Physics (ISTP) program, 1997-1999.
- Serves on the organizing committee for the International Heliophysical Year (IHY) in 2007, an international campaign of science and public outreach stemming from the 50-year anniversary of the International Geophysical Year (IGY) in 1957.
- Scientific advisor to the GeoHitchHiker (GHH) program, an initiative to identify opportunities to fly on commercial spacecraft for science and technology testbed equipment.
- Served as guest editor for a special volume of the Geophysical Research Letters.
- Coordinated a special issue of JASTP (Journal of Atmospheric and Solar-Terrestrial Physics), 1999.

Selected Publications

"Moreton Waves," B. J. Thompson, review in the Encyclopedia of Astronomy and Astrophysics, E. Priest, ed., Institute of Physics/Macmillan Press, publishers, 2001.

"Coronal Dimmings and Energetic CMEs in April-May 1998," B.J. Thompson, E.W. Cliver, N. Nitta, C. Delannee, J.-P. Delaboudiniere, Geophysical Research Letters, Vol. 27, No. 10, pp. 1431-1434, 2000.

"Observations of the September 24, 1997 Coronal Flare Waves," B.J. Thompson, B. Reynolds, H. Aurass, N. Gopalswamy, J.B. Gurman, H.S. Hudson, S.F. Martin, O.C. St. Cyr, Solar Physics, April 2000.

HARRY P. WARREN
NAVAL RESEARCH LABORATORY — DATA ANALYSIS SCIENTIST

EDUCATION

Ph.D., Plasma Physics, Columbia University, New York, New York
B.S., Physics, College of William and Mary, Williamsburg, Virginia

ACADEMIC HONORS

Sigma Xi, Columbia University
Phi Beta Kappa, College of William and Mary

EXPERIENCE

2002—Astrophysicist, Naval Research Laboratory
1998–2002—Astrophysicist, Smithsonian Astrophysical Observatory
1995–1998—Postdoctoral Research Scientist, Naval Research Laboratory

RESEARCH GRANTS

•Principal Investigator—"Impulsive Flare Dynamics," NASA's Sun-Earth Connection Guest Investigator program, 2002–2004.

•Principal Investigator—"The Development of a New Model of Solar EUV Irradiance Variability," NASA's Living With a Star program, 2001-2003.

•Principal Investigator—"The Origins of the Solar Wind," NASA's Sun-Earth Connection Guest Investigator program, 1999–2001.

RECENT JOURNAL PUBLICATIONS

Warren, H. P., A. R. Winebarger, and J. T. Mariska, Evolving active region loops observed with the Transition Region and Coronal Explorer: II. Time-Dependent hydrodynamic simulations, Astrophys. J., in press, 2003.

Winebarger, A. R., H. P. Warren, and D. B. Seaton, Evolving active region loops observed with the Transition Region and Coronal Explorer: I. Temporal evolution, Astrophys. J., submitted, 2003.

Lean, J. L., H. P. Warren, J. T. Mariska, and J. Bishop, A new model of solar EUV irradiance variability. II. Comparisons with empirical models and observations, and implications for space weather, J. Geophys. Res., 108, 1059– , 2003.

Winebarger, A. R., H. P. Warren, and J. T. Mariska, Transition Region and Coronal Explorer and Soft X-Ray Telescope Active Region Loop Observations: Comparisons with Static Solutions of the Hydrodynamic Equations, Astrophys. J., 587, 439–449, 2003.

Aschwanden, M. J., C. J. Schrijver, A. R. Winebarger, and H. P. Warren, A new method to constrain the iron abundance from cooling delays in coronal loops, Astrophys. J., 588, L49–L52, 2003.

Warren, H. P., A. R. Winebarger, and P. S. Hamilton, Hydrodynamic modeling of active region loops, Astrophys. J., 579, L41–L44, 2002.

Warren, H. P., and A. D. Warshall, Temperature and density measurements in a quiet coronal streamer, Astrophys. J., 571, 999–1007, 2002.

Amy Renee Winebarger

Naval Research Laboratory **Data Analysis Scientist**

Education

1995—B.S., Physics, King college, Bristol, Tennessee
1997—M.S., Physics, University of Alabama in Huntsville, Huntsville, Alabama
2000—Ph.D., Physics, University of Alabama in Huntsville, Huntsville, Alabama

Experience

2002-Present—Scientist, Computational Physics incorporated; Complete **TRACE** and **SOHO** data analysis at Naval Research Lab

1999-2001—Astrophysicist, Smithsonian Astrophysical Observatory; Study morphology and dynamics in the solar corona and transition region using observatories from TRACE and SUMER. Participate in TRACE planning and educational outreach programs.

Research Grants

Principal Investigator—"Analysis and Hydrodynamic Modeling of Active Region Loops" NASA's Solar and Heliospheric Physics program. 2002-2004.

Selected Publications

Winebarger, A. R., Warren, H. P., and Mariska, J. T., Quiescent Active Region Loops: Comparisons with Static Solutions of the Hydrodynamic Equations, 2003, Astrophys. J., 587, 439.

Winebarger, A. R., Warren, H. P., and Seaton, D. B., Evolving Active Region Loops Observed With the Transition Region and Coronal Explorer: I. Observations, 2003, Astrophys. J., submitted.

Warren, H. P., Winebarger, A. R., and Mariska, J. T., Evolving Active Region Loops Observed With the Transition Region and Coronal Explorer: II. Hydrodynamic Modeling, 2003 Astrophys. J., in press.

Aschwanden, M.J., Schrijver, C.J., Winebarger, A.R., and Warren, H.P. A New Method to Constrain the Iron Abundance from Cooling Delays in Coronal Loops, 2003, Astrophys. J 588, L49.

Winebarger, A.R., Warren, H.P., van Ballegooijen, A., DeLuca, E.E, and Golub, L, Steady Flows Detected in EUV Loops, 2002, Astrophys. J., 567, L89.

Winebarger, A.R., Updike, A.C., and Reeves, K.R., Correlating Transition Region Explosive Events with Extreme-Ultraviolet Brightenings, 2002, Astrophys. J., 570, L105.

Warren, H.P., Winebarger, A.R., and Hamiltion, P.S., Hydrodynamic Modeling of Active Region Loops, 2002 Astrophys. J., 579, L41.

Winebarger, A.R., DeLuca, E.E, and Golub, L., Dynamic Mass Flows Above an Active Region Observed with TRACE, 2001, Astrophys. J., 553, L81.

Warren, H.P. and Winebarger, A.R., Small-scale Structure in the Solar Transition Region, 2000, Astrophys. J., 535, L63.

1.0 BACKGROUND

Rutherford Appleton Laboratory, from The United Kingdom, is the only international partner on the NEXUS team. RAL is participating as science co-investigator, and is responsible for instrument calibration and ground station activities for the NEXUS Mission. As such, they will be responsible for developing and implementing the instrument calibration plan, in conjunction with the NEXUS science and engineering teams. In addition, they will provide the ground station for on-orbit operations, with mission and science operations conducted at GSFC.

2.0 DRAFT PLAN APPROACH

All NEXUS components, parts, and associated equipment specifically designed or modified for use in space-based systems are controlled under the ITAR 22 CFR Parts 120-130. The NEXUS PI is working with the GSFC Export Control Office to create a preliminary plan for use with RAL. At this time, it has been determined that a Letter of Agreement (LOA) between NASA and RAL will be needed for the NEXUS Mission. The preliminary analysis indicates that no export license will be needed but a license exemption, under 22 CFR126.4A2, will be necessary. During Phase B, a formal LOA will be signed by the cognizant Code I Division Director at NASA Headquarters, documenting the scope of our teaming arrangements with RAL. In addition, a Technical Assistance Agreement between our spacecraft contractor, Spectrum Astro, and RAL will be submitted to the Department of State for approval. Throughout the Mission life-cycle, all ITAR regulations will be strictly followed.

1.0 INTRODUCTION

The NEXUS Project at the Goddard Space Flight Center (GSFC) is collaborating with Rutherford Appleton Laboratory (RAL) in the United Kingdom to accomplish the Mission. A Letter of Agreement (LOA) is required pursuant to Section 203c of the National Aeronautics and Space Act of 1958 and to export control under ITAR definition 22 CFR Part 120.17 and 22 CFR 121.1.

2.0 PURPOSE

The purpose of this document is to outline the assignment of technical responsibilities between NASA and RAL for the instrument calibration and mission on-orbit operations for the Mission. No hardware or software can be approved for export to RAL without a signed international agreement in place.

3.0 NASA RESPONSIBILITIES

The following is an overview of the NASA responsibilities for the LOA:

- Manage the NEXUS project, including all development and test activities for the observatory, and mission and science operations centers;
- Obtain the necessary approvals for transportation and delivery of the NEXUS instrument and associated test equipment to and from designated RAL facilities in the U.K., for calibration;
- Develop all flight and ground hardware and software, and maintain ownership;
- Export all appropriate interface control documents necessary for conducting ground station activities from RAL during on-obit operations;
- Manage all NEXUS instrument and spacecraft reviews; and
- Launch and operate the NEXUS observatory.
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4.0 RAL RESPONSIBILITIES

The following is an overview of the RAL responsibilities that will be described in the LOA:

- Participate in the preparation and implementation of the NEXUS instrument calibration activities;
- Provide all facilities necessary to conduct calibration of the NEXUS instrument;
- Provide all ground station facilities necessary to accommodate all uplink and downlink requirements for the Mission;
- Participate in the documentation of the interface between the RAL ground station and the GSFC mission operations center;
- Provide personnel to support and maintain the NEXUS ground station for the duration of Mission operations; and
- Participate in the development of the NEXUS Step 2 proposal.

We anticipate that natural disposal of the NEXUS observatory will occur during atmospheric reentry due to the accumulated effects of atmospheric drag. Due to its similarity to previous missions which underwent natural disposal during reentry, safe disposal by controlling the footprint of reentry debris will not be required.

In compliance with NPD 8710.3, The NEXUS team will conduct a formal assessment during Phase A of the orbital debris the observatory will create upon mission termination.

1.0 SERVICES OF THE NON-GOVERNMENT PARTICIPANTS AVAILABLE UNDER AN EXISTING NASA CONTRACT

The spacecraft vendor, Spectrum Astro, was selected under GSFC's Rapid Spacecraft Development Office contract. This was a competitively selected contract awarded after release of a Request for Offer. See the attached letter certifying the process for selecting contractors.

2.0 SELECTION PROCESS OF NON-GOVERNMENT CO-INVESTIGATORS (CO-IS)

All of the non-Government Co-Is were selected based on their unique ability to add to the Mission scientific return within cost and technical capabilities. The Co-Is were solicited and selected based on open discussions. Those institutions, representatives, and unique contributions are noted below:

- Universities Space Research Association
    - Scott McIntosh—Providing data analysis in the areas of dynamic and wave effects
- The Catholic University of America
    - Jeffrey Brosius—Providing implementation of the E/PO program and data analysis
    - Leon Ofman—Providing solar wind and coronal loop modes to compare with observations
- Rutherford Appleton Laboratory
    - Richard Harrison—Providing calibration facility and implementation
    - James Lang—Providing pre-flight calibration support and data analysis
    - David Pike—Providing planning and archiving tool software based on CDS/Solar-B software
- University of California – Berkeley
    - Oswald Siegmund—Providing image intensifier assemblies

3.0 PRINCIPAL INVESTIGATOR HAS NO CONFLICT OF INTEREST

Joseph Davila, PI for the NEXUS Mission, has examined his financial interests in or concerning the entire proposal team and found no personal conflicts of interest exist. See the attached letter certifying that the PI has no personal conflict of interest.

ACE. . . . . . . Advanced Composition Explorer
ACS. . . . . . . Attitude Control System
ADE . . . . . . Array Drive Electronics
A-HR. . . . . . Ampere-hours
AO. . . . . Announcement of Opportunity
ARGOS . . . . Advanced Research and Global Observation Satellite
ASTRO . . . . Antarctic Submillimeter Telescope and Remote Observatory
BER. . . . . . . Bit Error Rate
BOE. . . . . . . Basis of Estimate
C&DH. . . . . Command and Data Handling
C/NOFS . . . Communication/Navigation Outage Forecasting System
CCB . . . . . . Configuration Control Board
CCD . . . . . . Charge Coupled Device
CCSDS . . . . Consultative Committee for Space Data Systems
CCU . . . . . . Charge Control Unit
CDR . . . . . . Critical Design Review
CDS. . . . . . . Coronal Diagnostic Spectrometer
CG. . . . . Center of Gravity
CME . . . . . . Coronal Mass Ejection
CPLD . . . . . Complex Programmable Logic Device
CPU. . . . . . . Central Processing Unit
CSS . . . . Coarse Sun Sensor
CUA . . . . . . The Catholic University of America
DDM . . . . . . Detector Door Mechanism
DL . . . . Downlink
DOD . . . . . . Depth of Discharge
DPM . . . . . . Deputy Project Manager
DRAM . . . . Dynamic Random Access Memory
E/PO . . . . . . Education and Public Outreach
EEPROM . . Electronically Erasable Programmable Read-Only Memory
EIRP . . . . . . Effective Isotropic Radiated Power
EIS. . . . . EUV Imaging Spectrometer
EIT . . . . Extreme-ultraviolet Imaging Telescope
EM. . . . . Engineering Model
EMI/EMC . . Electromagnetic Interference/ Electromagnetic Compatibility
EOL. . . . . . . End-of-Life
ESA. . . . . . . European Space Agency
ESD. . . . . . . Electrostatic Discharge
EUNIS. . . . . Extreme Ultraviolet Normal Incidence Spectrograph
EUV . . . . . . Extreme Ultraviolet
EUVE . . . . . Extreme UltraViolet Explorer
EVE . . . . . . Extreme-Ultraviolet Experiment
FITS . . . . . . Flexible Image Transport System
FOT. . . . . . . Flight Operations Team
FOV . . . . . . Field of View
FPGA . . . . . Field Programmable Gate Array
FUSE . . . . . Far Ultraviolet Spectroscopic Explorer
GaAs. . . . . . Gallium Arsenide
Gbyte . . . . . Gigabyte
GG . . . . Gravity Gradient
GLAST . . . . Gamma-Ray Large Area Space Telescope
GOES . . . . . Geostationary Operational Environmental Satellite
GSE. . . . . . . Ground Support Equipment
GSFC . . . . . NASA's Goddard Space Flight Center
HA . . . . Hazard Analysis
HAPS . . . . . Hydrazine Auxillary Propulsion System
HK . . . . Housekeeping
HRTS . . . . . High Resolution Telescope Spectrometer
Hz . . . . Hertz
I&T . . . . Integration and Test
ICCD. . . . . . Intensified CCD
IDL . . . . Interactive Data Language
IEM. . . . . . . Integrated Electronics Module
IM . . . . Instrument Manager
IMU . . . . . . Inertial Measurement Unit
IPCU. . . . . . Integrated Power Converter Unit
IRAS. . . . . . Infrared Astronomical Satellite
IRD . . . . International Radiation Detector
ITAR. . . . . . International Traffic in Arms Regulations
L/D . . . . Length to Diameter Ratio
L&EO . . . . . Launch and Early Orbit
LASCO. . . . Large Angle Spectrometric Coronagraph
LOA . . . . . . Letter of Agreement
LV. . . . . Launch Vehicle
LVDS . . . . . Low Voltage Differential Signaling
LWS . . . . . . Living With a Star
MAR. . . . . . Mission Assurance Requirements
MBM . . . . . Mission Business Manager
MCP . . . . . . Microchannel Plate
MEB . . . . . . Main Electronics Box
MHD. . . . . . Magnetohydrodynamic(s)
MHz . . . . . . Megahertz
MK . . . . MegaKelvin
MLI. . . . . . . Multi-layer Insulation
MM. . . . . . . Minimum Mission

MO&DA . . . Mission Operations and Data Analysis
MOC . . . . . . Mission Operations Center
MOLEFLUX Molecular Flux
MOM . . . . . Mission Operations Manager
MSM . . . . . . Mission Systems Manager
MSTI . . . . . . Miniature Sensor Technology Integration
MTF . . . . . . Modulation Transfer Function
MTR . . . . . . Magnetic Torque Rod
NASA . . . . . National Aeronautics and Space Administration
NEXUS . . . . Normal-incidence Extreme Ultraviolet Spectrograph
NiCd . . . . . . Nickel-Cadmium
NOAA . . . . . National Oceanic and Atmospheric Administration
NRL. . . . . . . Naval Research Laboratory
NSSDC . . . . National Space Science Data Center
OAP . . . . . . Orbit Average Power
OQPSK . . . . Offset Quadrature Phase Shift Keying
ORFEUS . . . Orbiting Retrievable Far and Extreme Ultraviolet Spectrograph
OSS . . . . Office of Space Science
PACI . . . . . . Payload and Attitude Control Interface
PCI . . . . Peripheral Component Interface
PDR. . . . . . . Preliminary Design Review
PDU . . . . . . Power Distribution Unit
PI. . . . . Principal Investigator
PM. . . . . Project Manager
PRICE H . . . Parametric Review of Information for Costing and Evaluation Hardware
QL . . . . Quick-Look
QMS . . . . . . Quality Management System
RAL. . . . . . . Rutherford Appleton Laboratory
RAO . . . . . . Resource Analysis Office
RHC . . . . . . Right Hand Circular
RHESSI. . . . Reuven Ramaty High Energy Solar Spectroscopic Imager
RMS . . . . . . Root Mean Square
RSDO . . . . . Rapid Spacecraft Development Office
Rx . . . . Receive/Receiver
s. . . . . Second(s)
S/C . . . . Spacecraft
SA . . . . Solar Array
SADA . . . . . Solar Array Drive Assembly
SAM . . . . . . System Assurance Manager
SB . . . . Small Business
SDAC . . . . . Solar Data Analysis Center at GSFC
SDB . . . . . . Small Disadvantaged Business
SDO . . . . . . Solar Dynamics Observatory
SECCHI . . . Sun-Earth Connection Coronal and Heliospheric Investigation
SECEF . . . . Sun-Earth Connection Education Forum
SELVS . . . . Small Expendable Launch Vehicle Services
SEMP . . . . . Systems Engineering Management Plan
SERTS . . . . Solar Extreme-ultraviolet Rocket Telescope and Spectrograph
SHARPP. . . Solar Heliospheric Activity Research and Prediction Package
SMEX. . . . . Small-class Explorers
SOC . . . . . . Science Operations Center
SOH . . . . . . State-of-Health
SOHO. . . . . Solar and Heliospheric Obsevatory
SORCE. . . . Solar Radiation and Climate Experiment
SSL . . . . Space Science Laboratory
SSM . . . . . . Solid State Memory
STA. . . . . . . Star Tracker Assembly
STDN . . . . . Space Tracking and Data Network
STEREO . . . Solar Terrestrial Relations Observatory
STOP . . . . . Structural, Thermal, Optical Performance
SUMER . . . Solar Ultraviolet Measurement of Emitted Radiation
SVLS . . . . . Spherical Varied Line-Space
SWAS. . . . . Submillimeter Wave Astronomy Satellite
SXI . . . . Solar X-ray Imager
SXT. . . . . . . Soft X-ray Telescope on Yohkoh
TAM . . . . . . Three-Axis Magnetometer
TCS. . . . . . . Thermal Control Subsystem
TCXO . . . . . Temperature Compensated Crystal Oscillator
TDRS . . . . . Tracking and Data Relay Satellite
TPM . . . . . . Technical Performance Measures
TRACE. . . . Transition Region and Coronal Explorer
TVLS . . . . . Toroidal Varied-Line-Space
Tx . . . . Transmit/Transmitter
UCB . . . . . . University of California, Berkeley
UDL . . . . . . Uplink/Downlink
UIT . . . . Ultraviolet Imaging Telescope
UL. . . . . Upload

USRA . . . . . Universities Space Research Association
UT . . . . Universal Time
UV. . . . . Ultraviolet
UVCS . . . . . Ultraviolet Coronagraph Spectrometer
V . . . . Volt(s)
VAULT. . . . Very high Angular resolution ULtraviolet Telescope
VME . . . . . . Versa Module Eurocard
VSO . . . . . . Virtual Solar Observatory
WBS . . . . . . Work Breakdown Structure
WIRE . . . . . Wide-Field Infrared Explorer
WLHS . . . . . Wild Lake High School, Columbia, MD
WLMS . . . . Wild Lake Middle School, Columbia, MD
WTR . . . . . . Western Test Range

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